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Scott et al.

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(54) **SURGICAL CLIP APPLIER WITH WIDE APERTURE SURGICAL CLIPS**

(71) Applicant: **Ethicon LLC**, Guaynabo, PR (US)

(72) Inventors: **Gregory Scott**, Cincinnati, OH (US); **Michael J. Stokes**, Cincinnati, OH (US); **Disha Labhasetwar**, Cincinnati, OH (US)

(73) Assignee: **Ethicon LLC**, Guaynabo, PR (US)

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A61B 17/29	(2006.01)
A61B 17/10	(2006.01)
A61B 34/30	(2016.01)
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CPC ***A61B 17/1285*** (2013.01); ***A61B 17/122*** (2013.01); ***A61B 34/25*** (2016.02); ***A61B 34/37*** (2016.02); *A61B 17/10* (2013.01); *A61B 34/70* (2016.02); *A61B 2017/00477* (2013.01); *A61B 2017/2939* (2013.01); *A61B 2034/305* (2016.02)

(58) **Field of Classification Search**

CPC ... A61B 17/10; A61B 17/068; A61B 17/0682; A61B 17/00684

See application file for complete search history.

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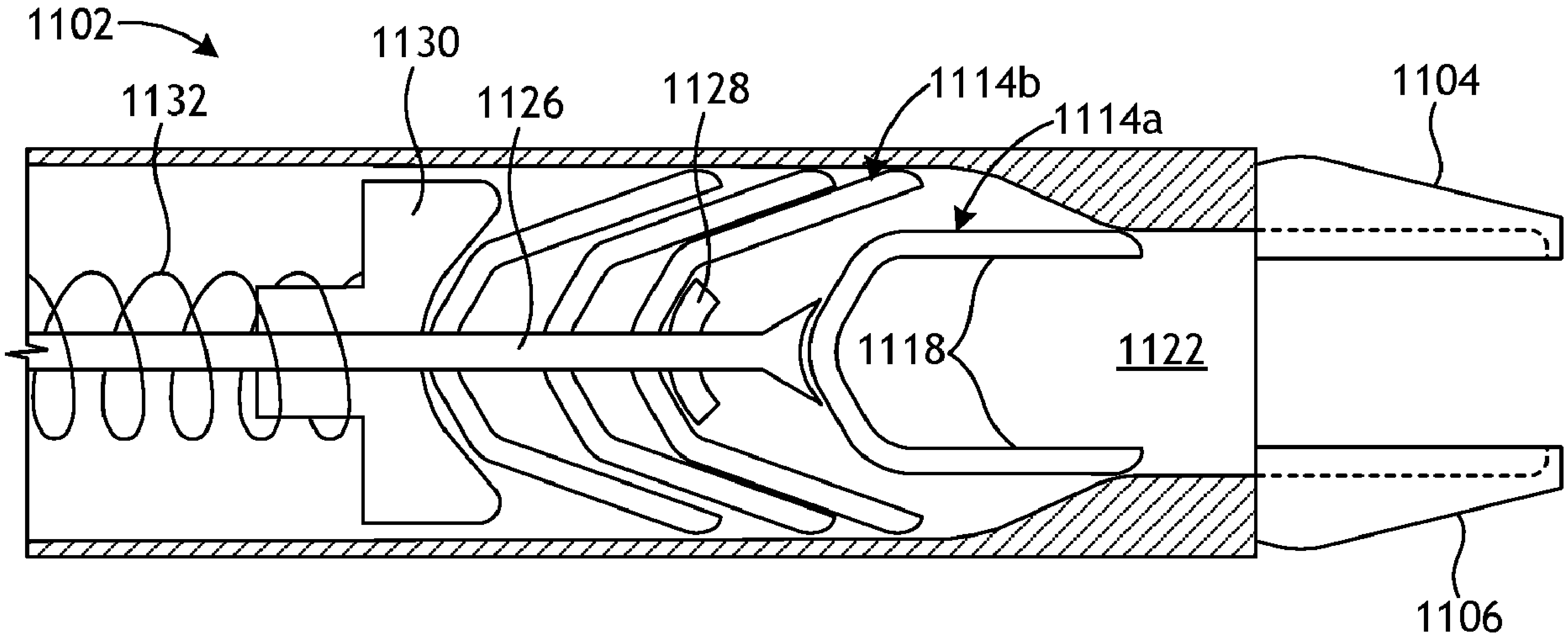
Primary Examiner — Alexander J Orkin

(74) *Attorney, Agent, or Firm* — Vorys, Sater, Seymour and Pease LLP

(57) **ABSTRACT**

An end effector for a surgical clip applier includes an elongate body and a clip track provided within the body and containing one or more surgical clips. Each surgical clip includes a crown and a pair of legs extending longitudinally from the crown and diverging from each other at a diverging opening angle. A pre-forming region is provided within the body and arranged to receive and deform the one or more surgical clips from a first state, where the pair of legs diverge at the diverging opening angle, and a second state, where the diverging opening angle is minimized. First and second jaw members are positioned at a distal end of the body and arranged to receive the one or more surgical clips from the pre-forming region in the second state.

15 Claims, 14 Drawing Sheets



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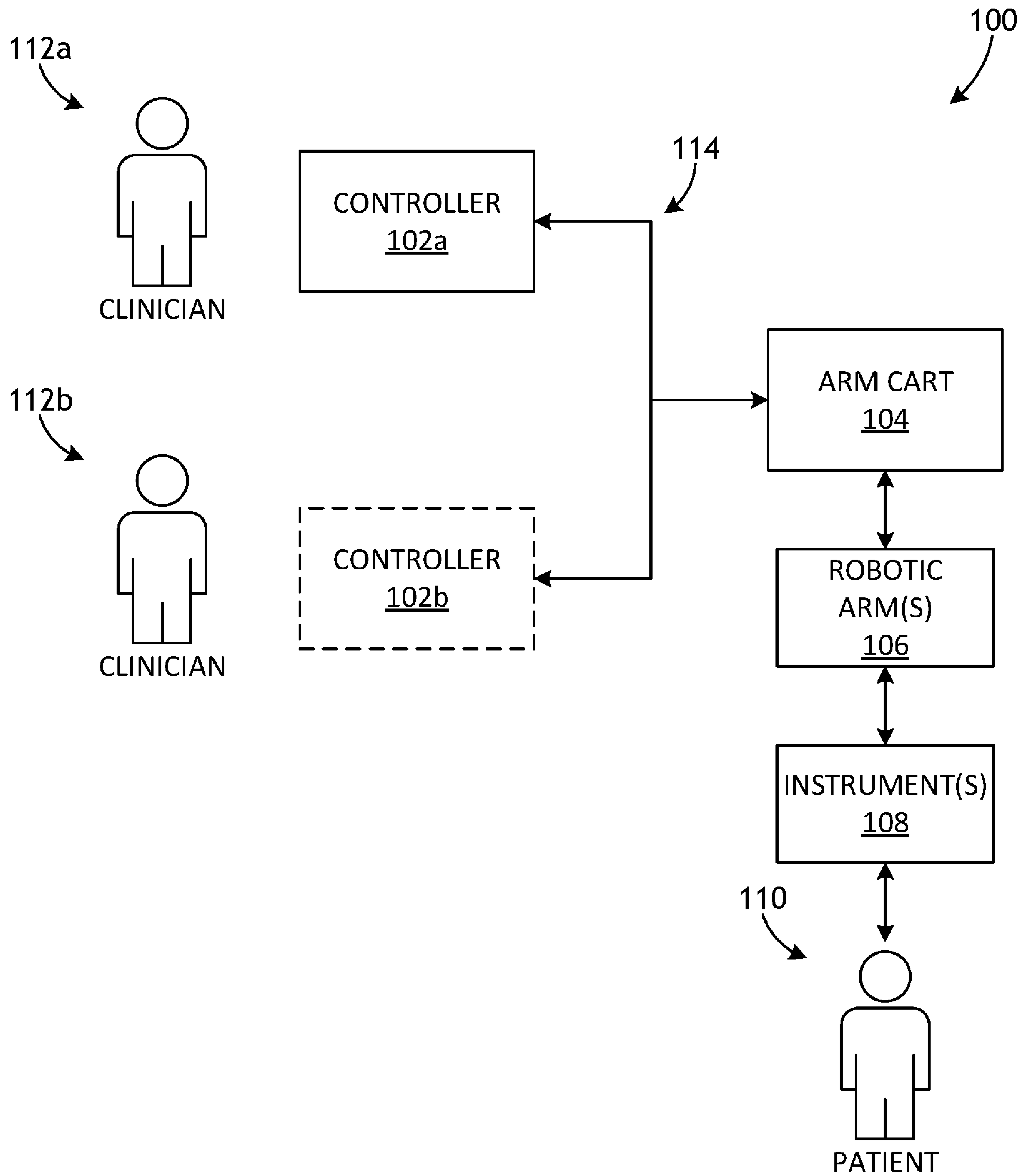


100
112a
CLINICIAN
CONTROLLER
102a
114
112b
CLINICIAN
CONTROLLER
102b
ARM CART
104
ROBOTIC
ARM(S)
106
INSTRUMENT(S)
108
110
PATIENT

FIG. 1

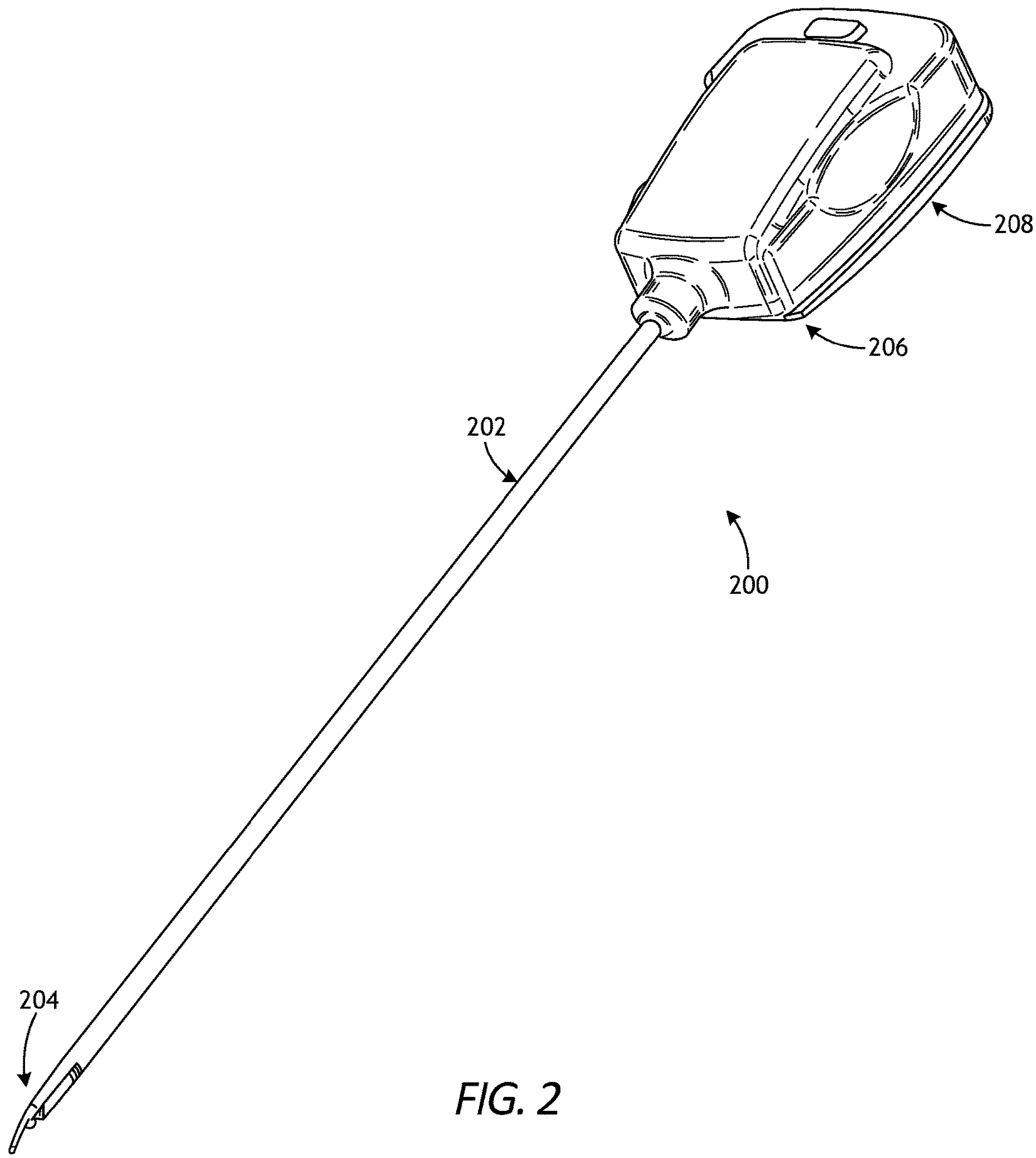


FIG. 2

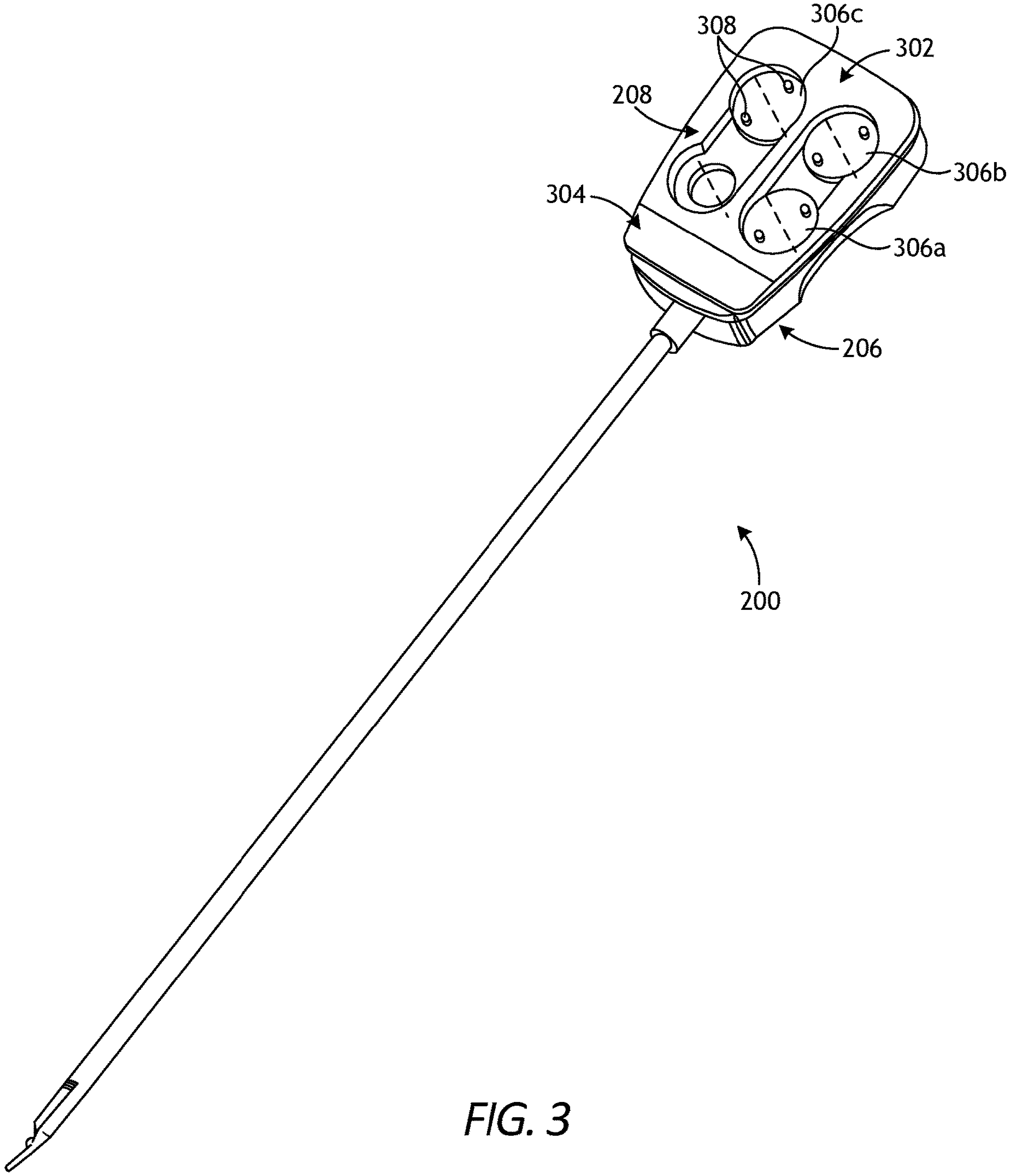
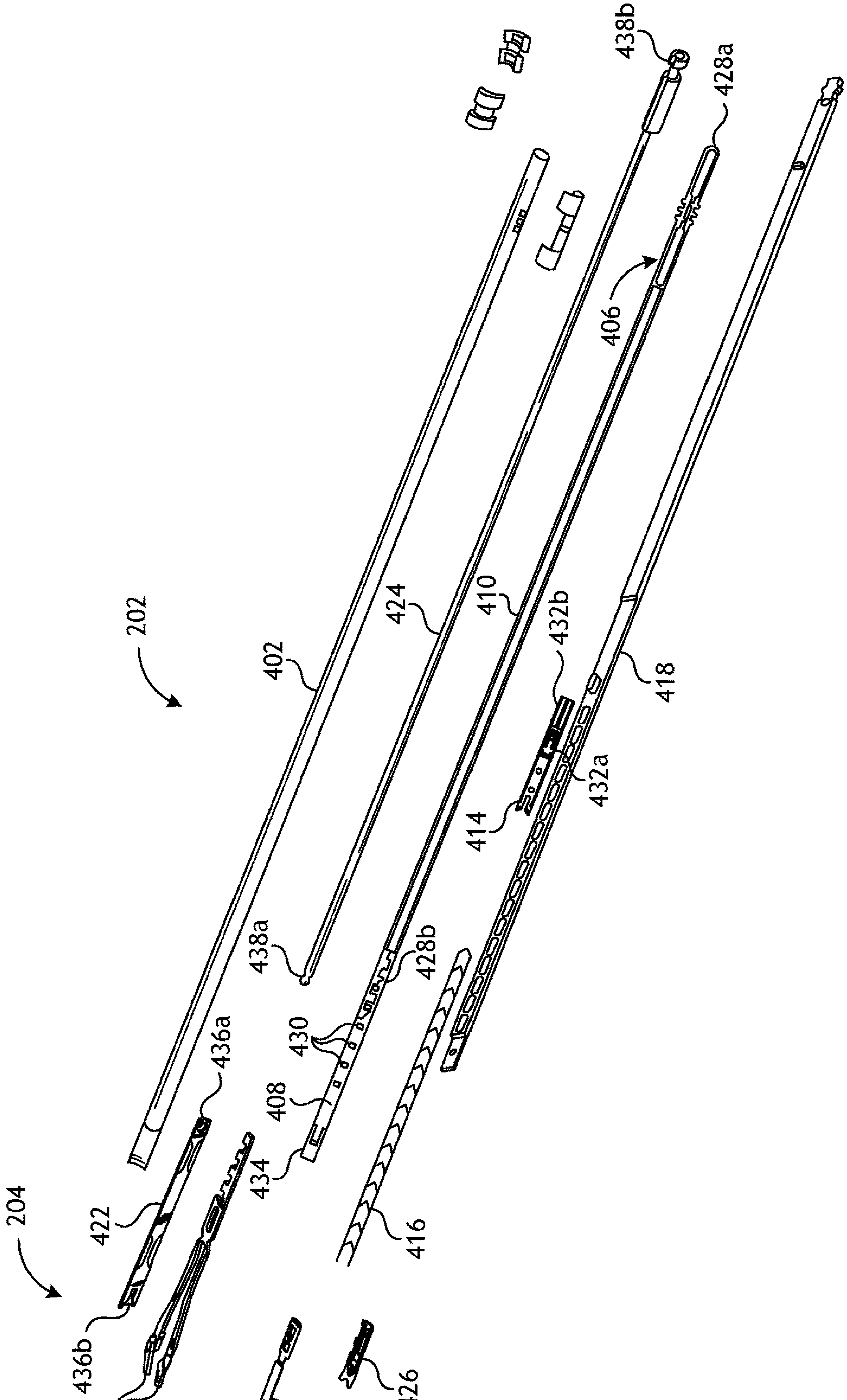


FIG. 3


202
402
424
410
406
438b
428a
418
432b
432a
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438a
428b
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436a
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436b
412
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420
426
416

FIG. 4

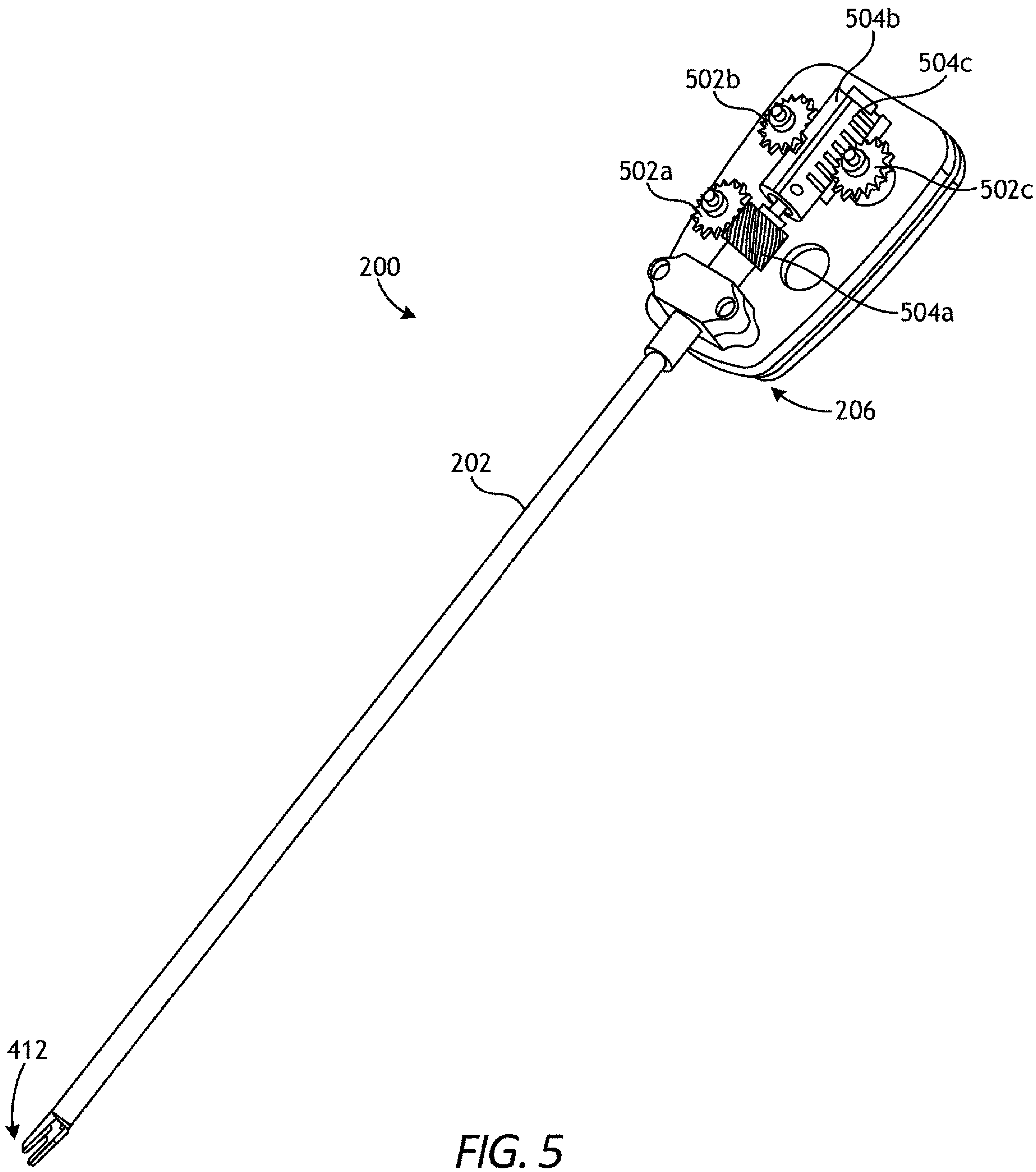
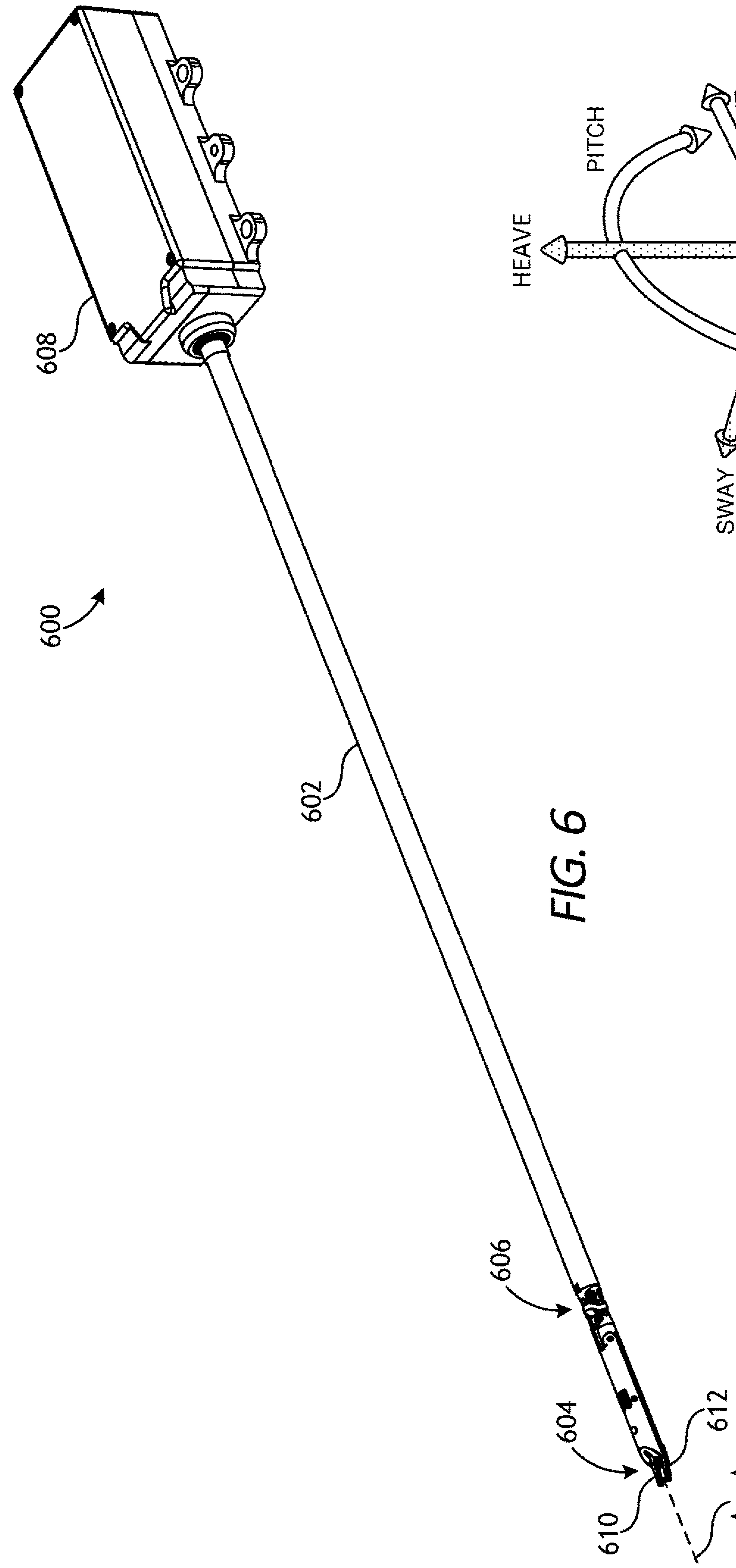


FIG. 5


608
600
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612
610
A1, A2

FIG. 6

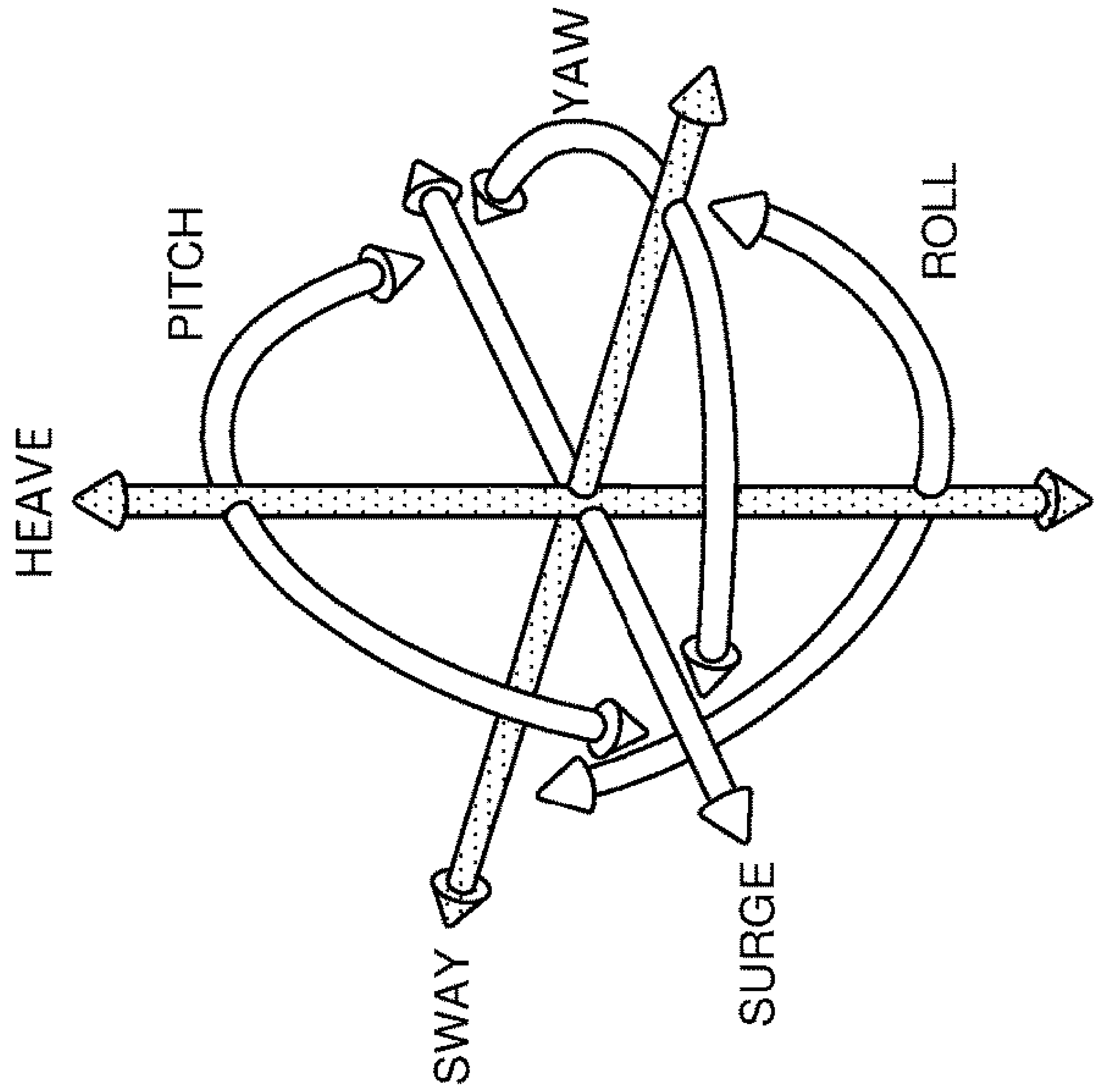
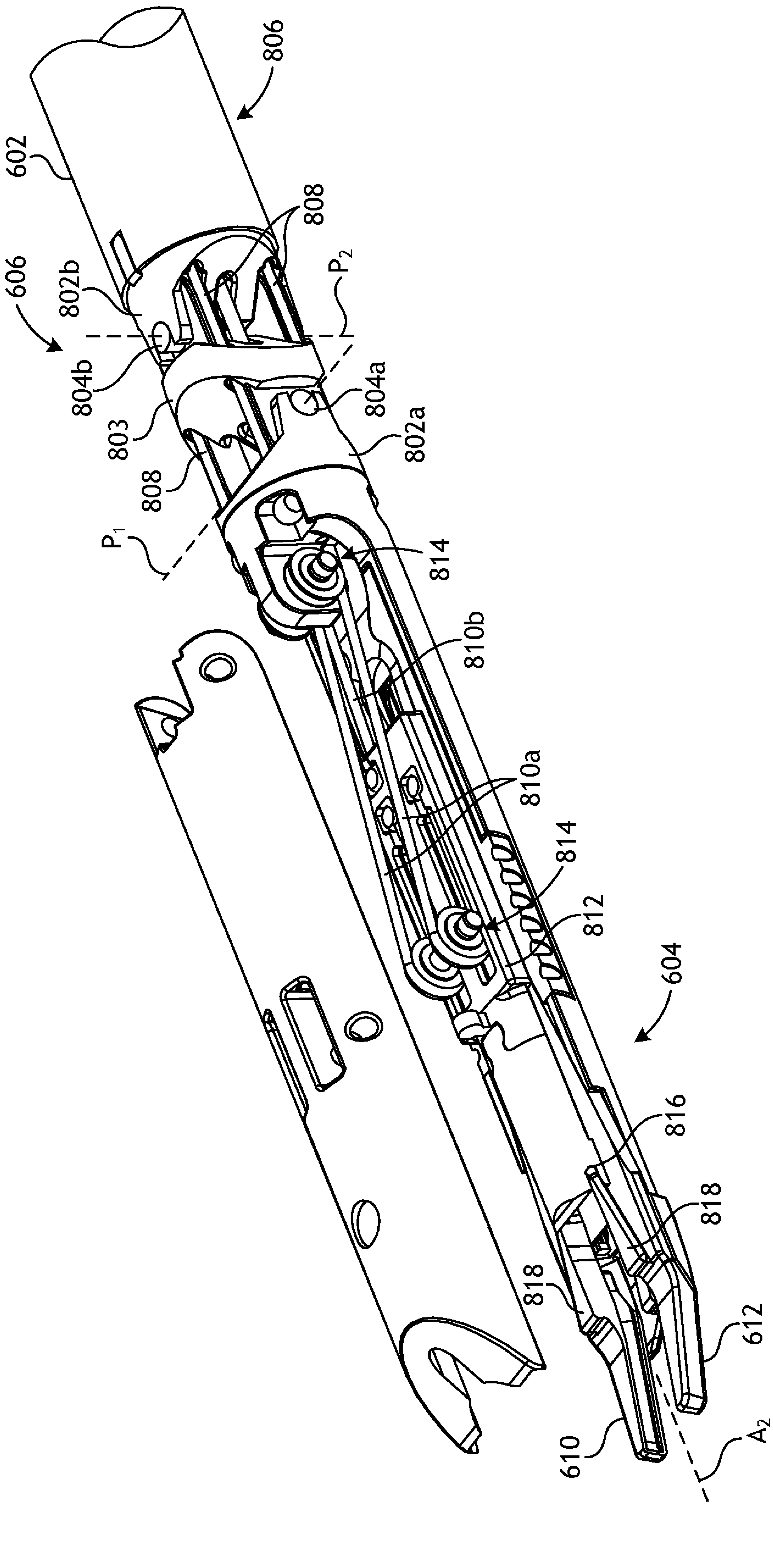

HEAVE
PITCH
YAW
ROLL
SWAY
SURGE

FIG. 7


806
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808
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802b
P_2
804b
804a
803
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P_1
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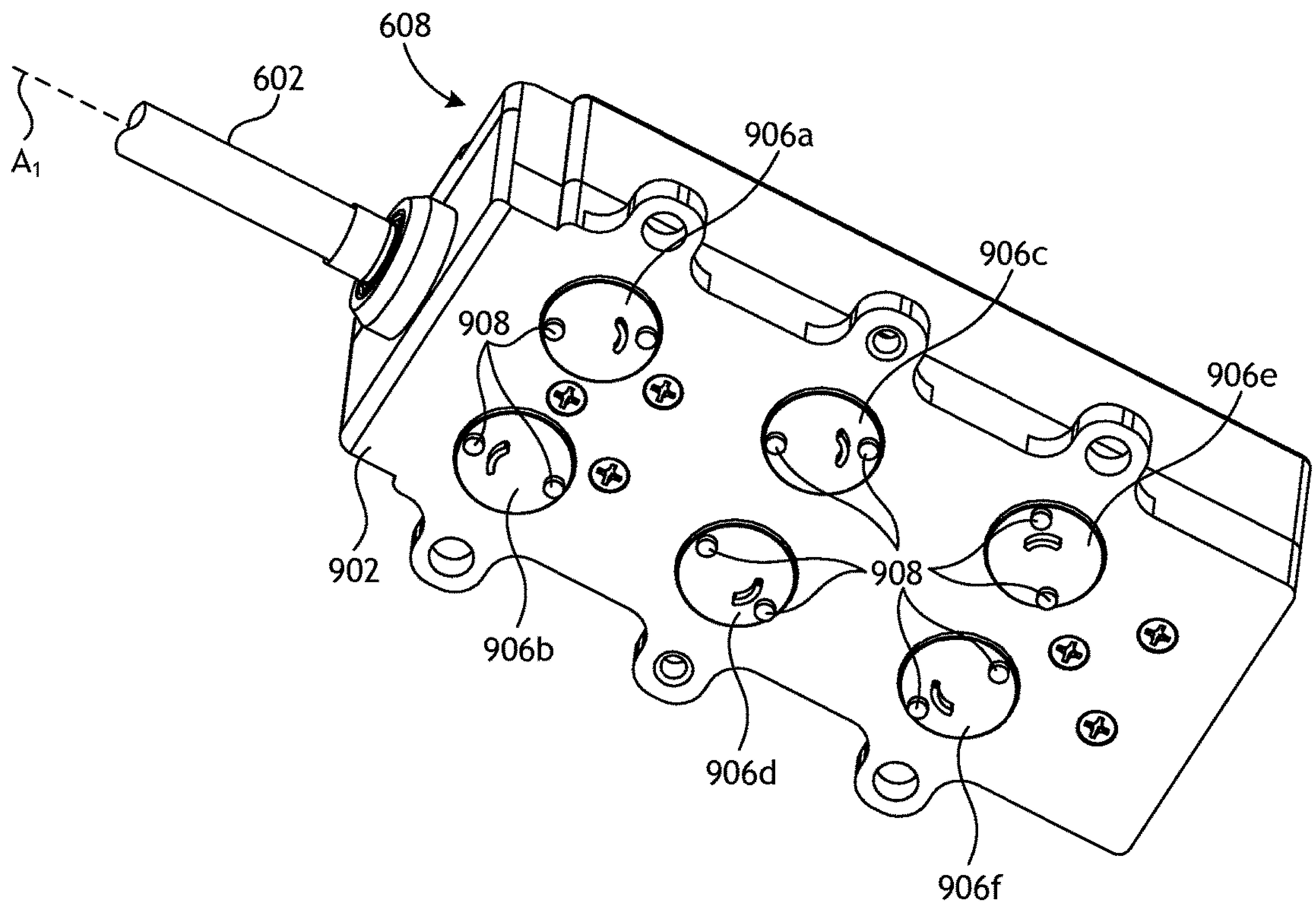
610
A_2

FIG. 8


608
602
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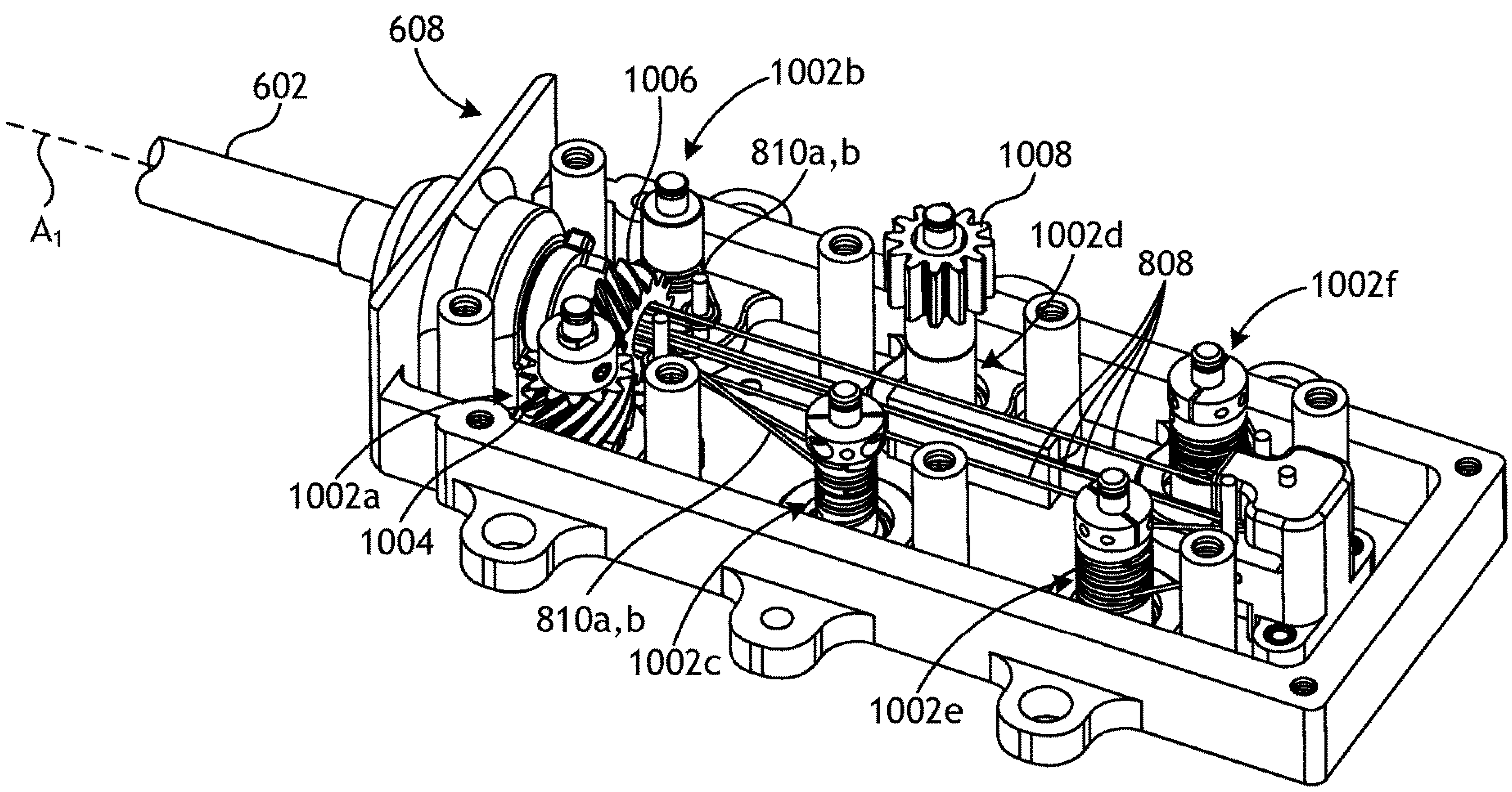
906a
906c
908
906e
902
908
906b
906d
906f

FIG. 9


608
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1006
1002b
810a,b
1008
1002d
808
1002f
1002a
1004
810a,b
1002c
1002e

FIG. 10

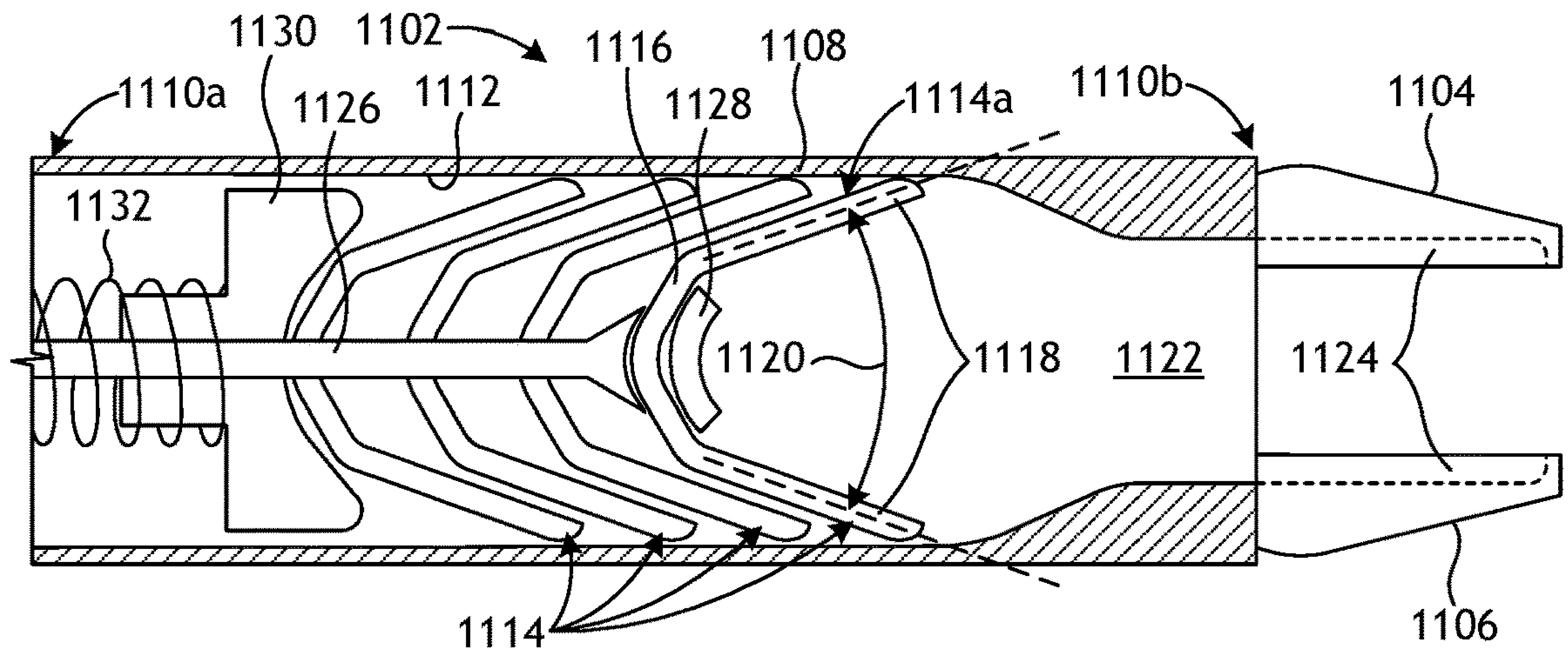

FIG. 11A

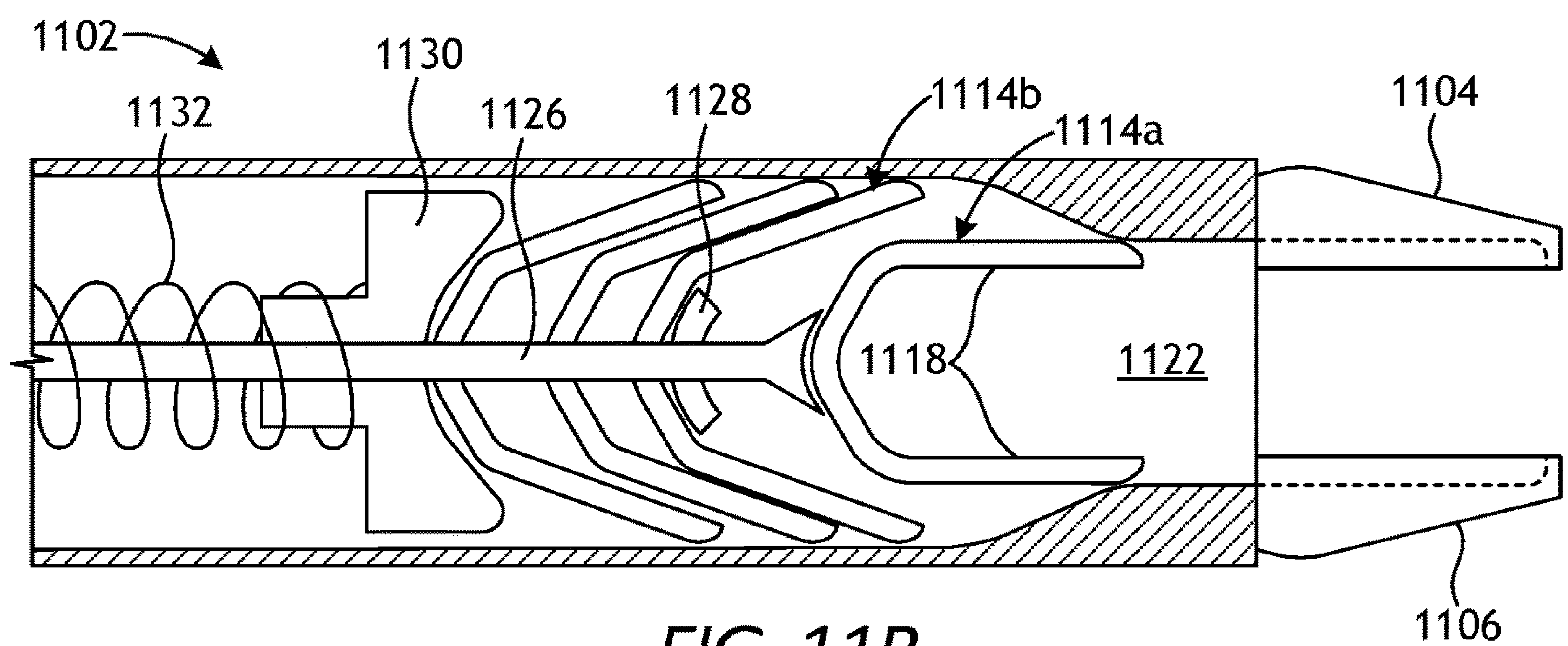

FIG. 11B

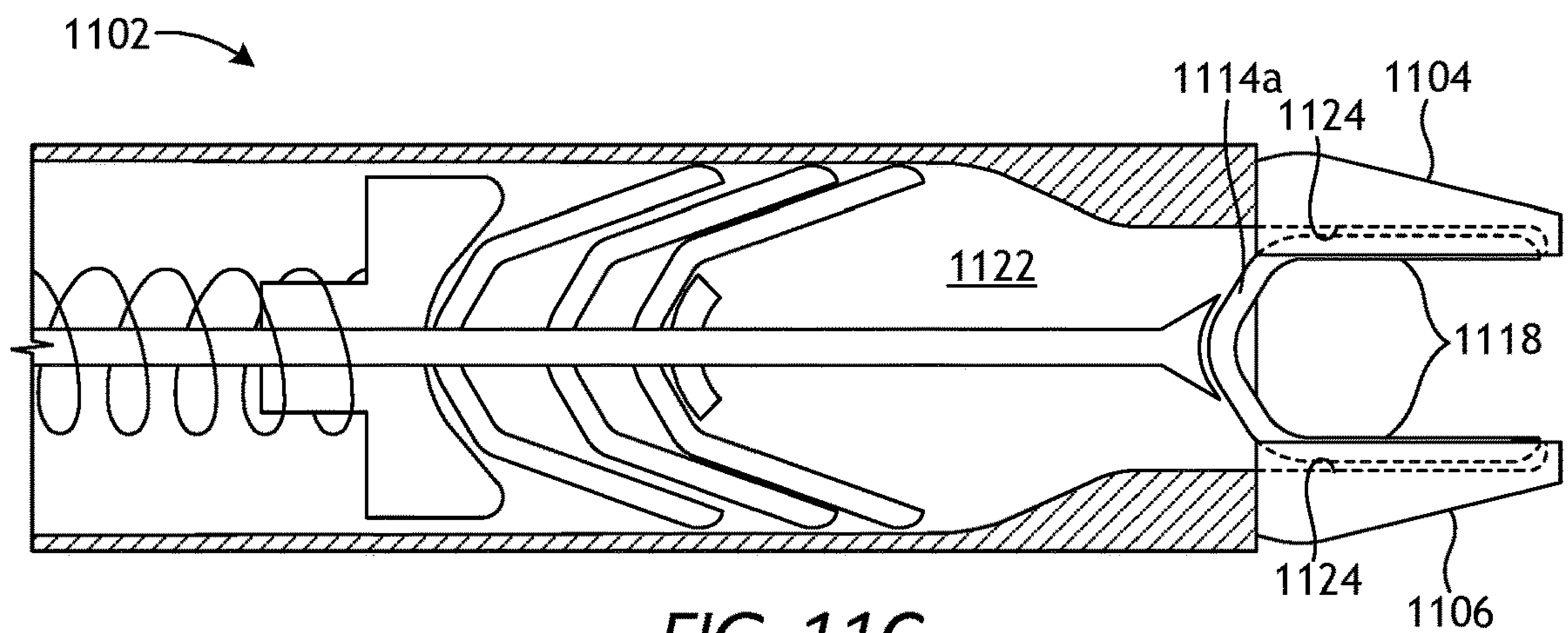

FIG. 11C

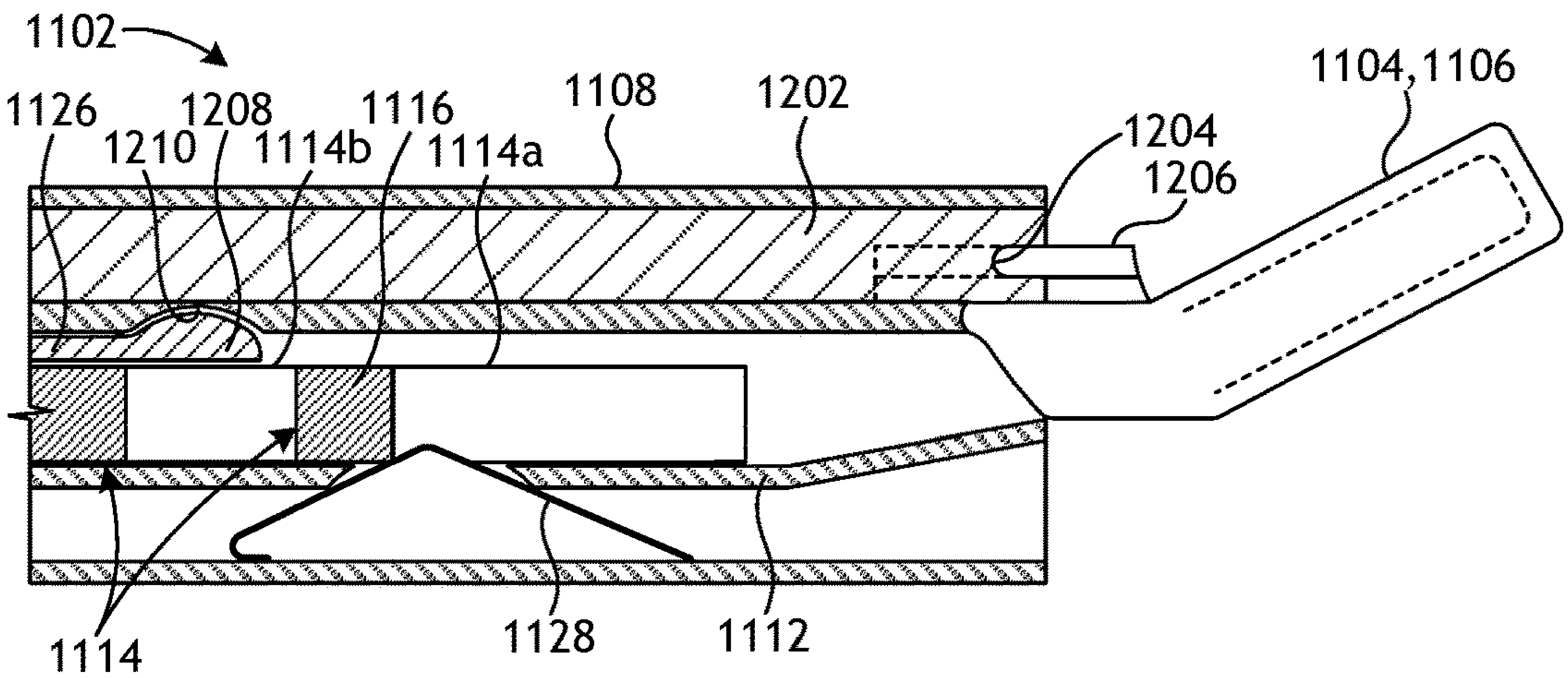

FIG. 12A

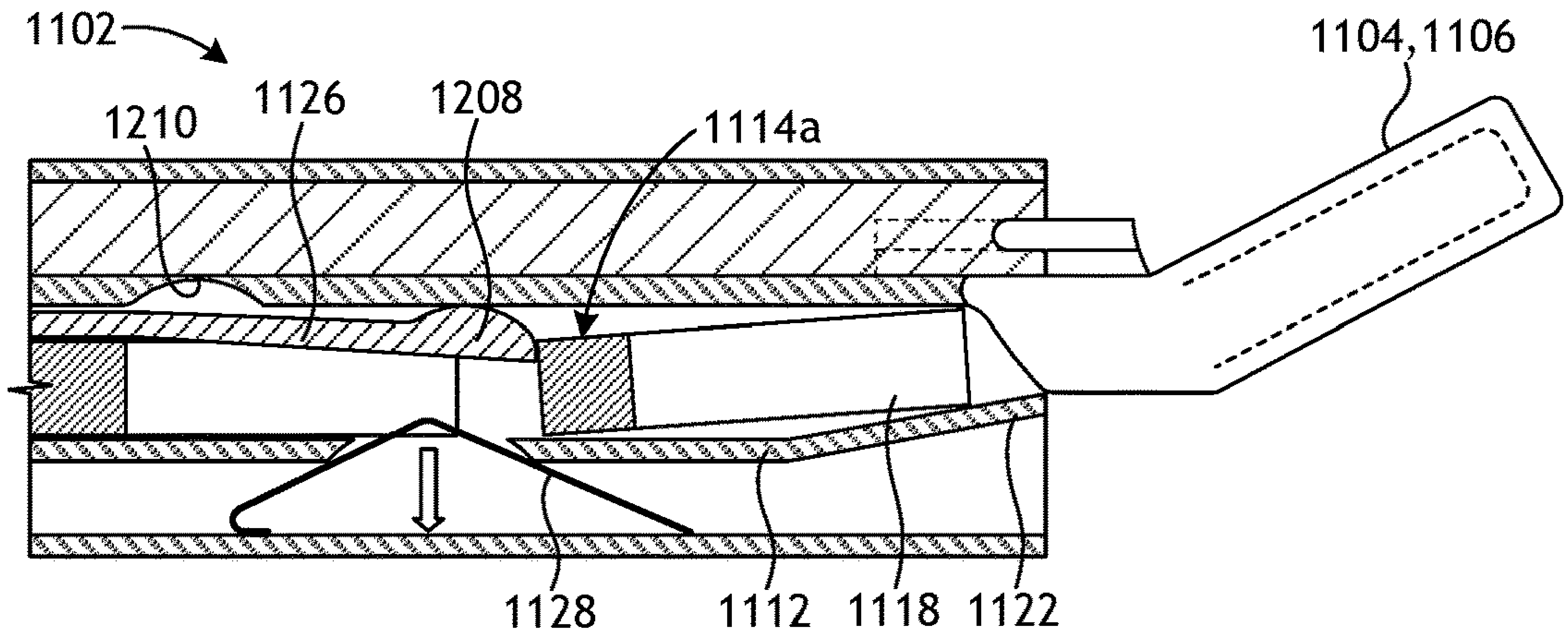

FIG. 12B

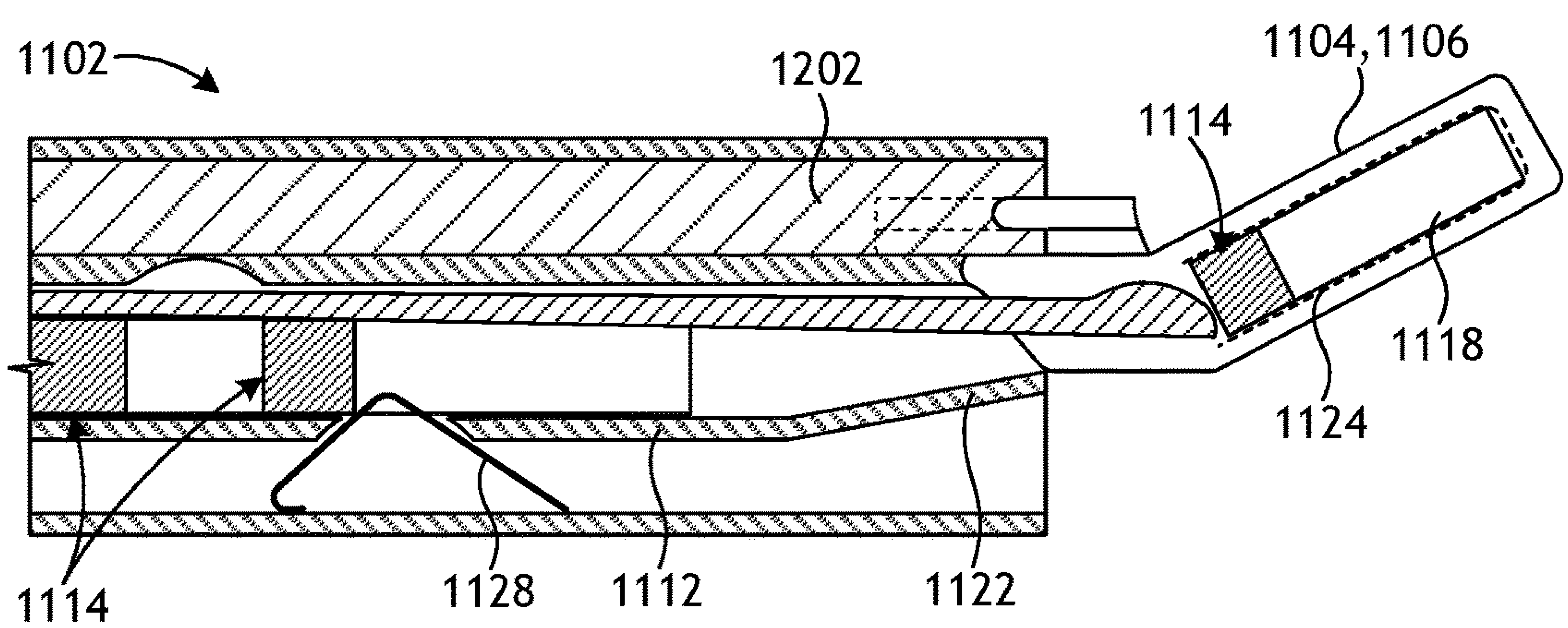

FIG. 12C

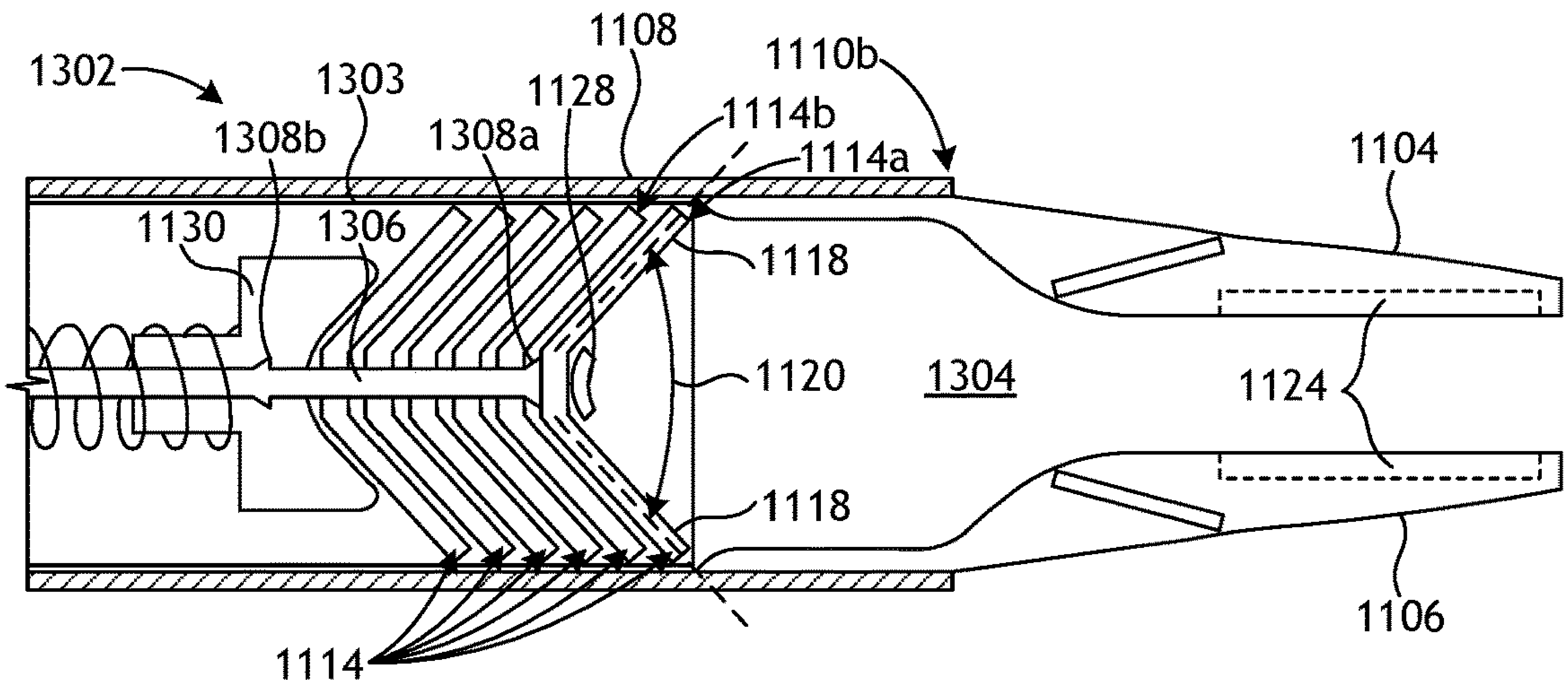

FIG. 13A

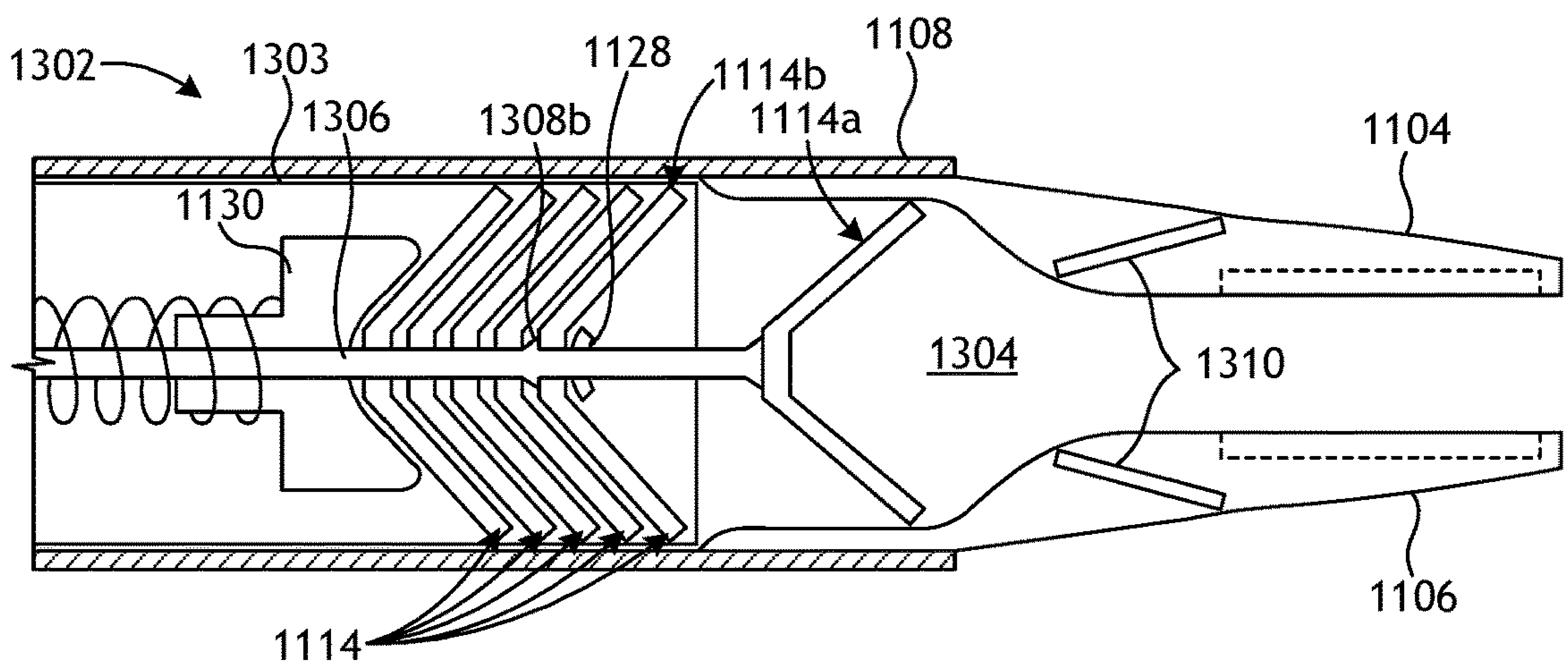

FIG. 13B

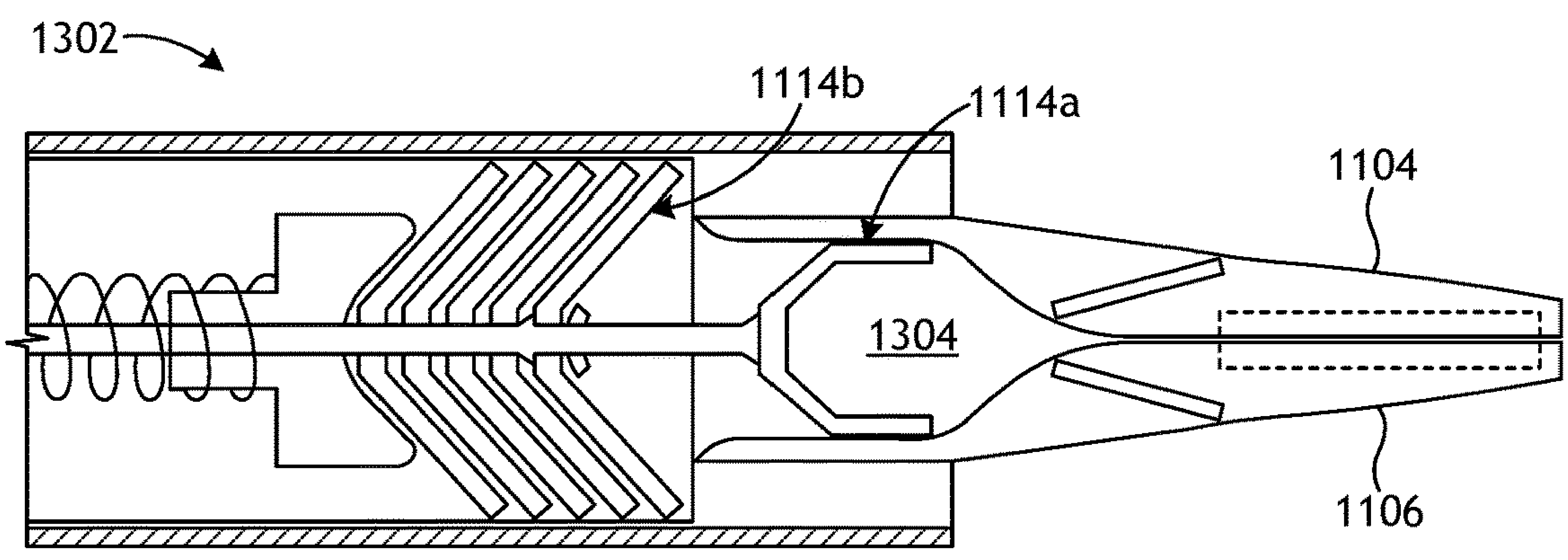

FIG. 13C

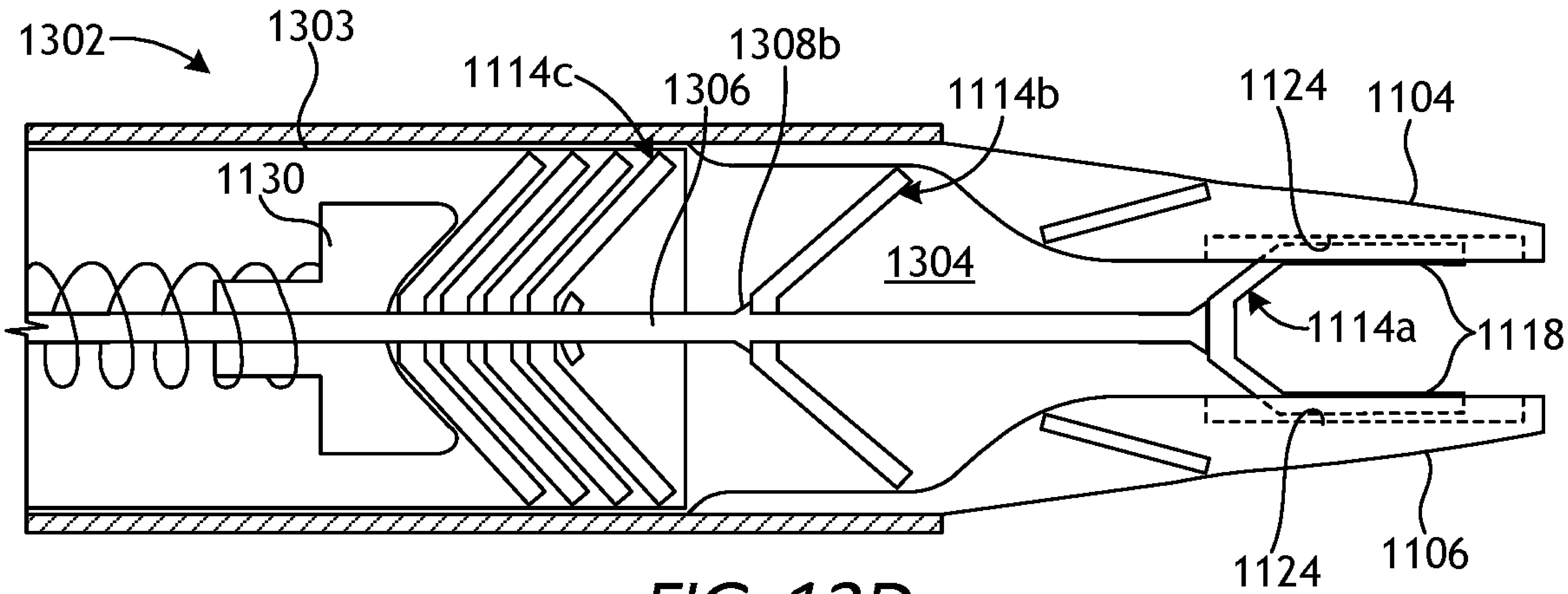

FIG. 13D

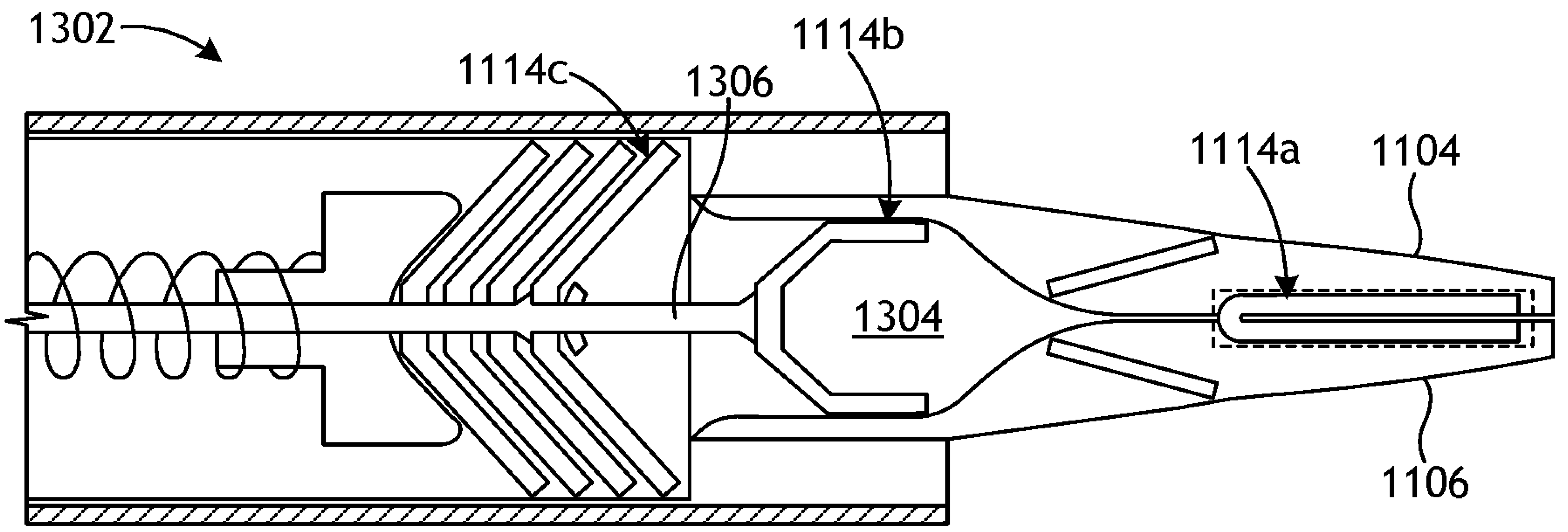

FIG. 13E

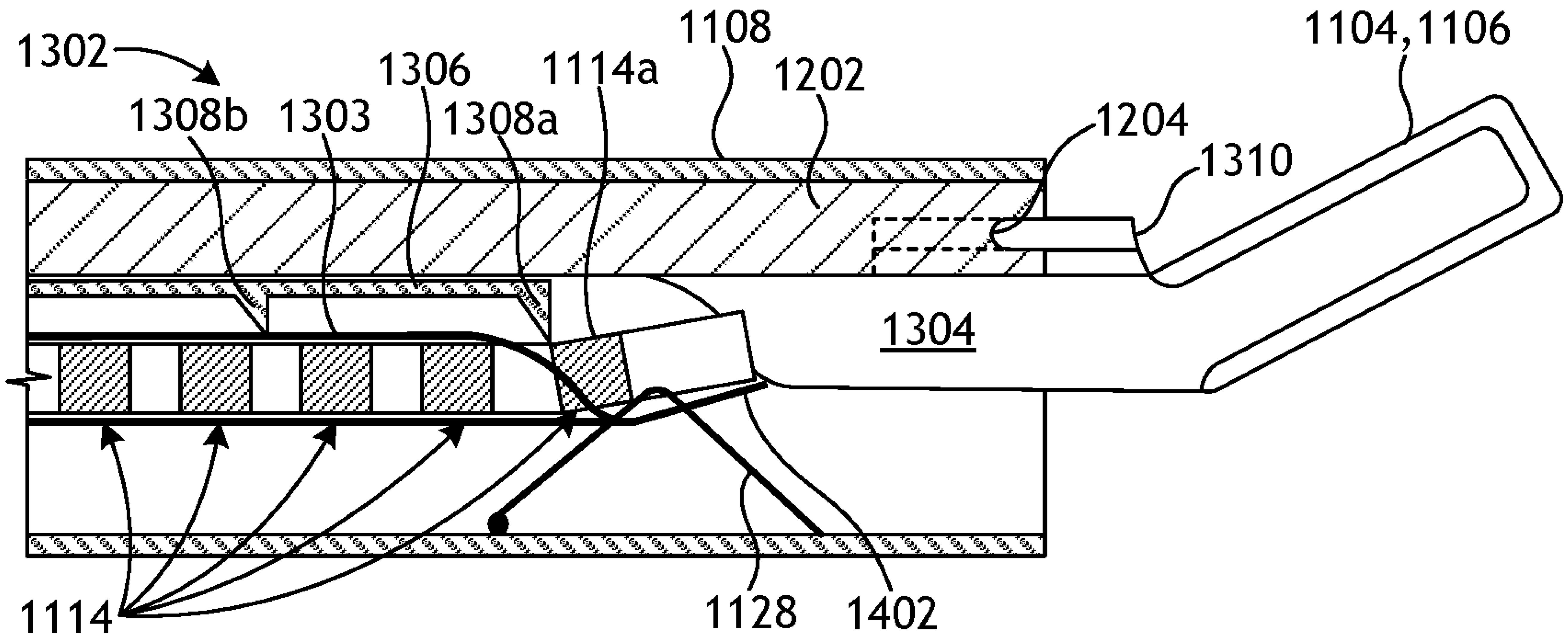

FIG. 14A

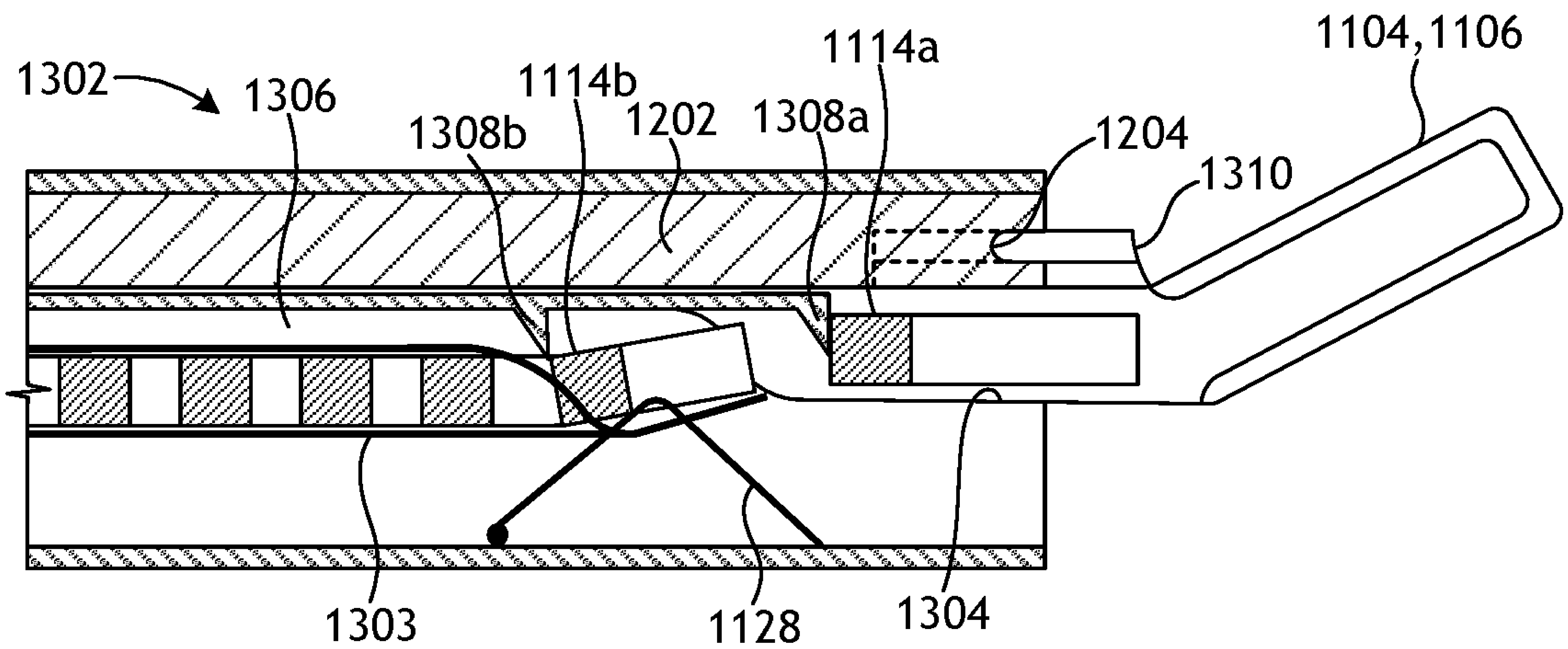

FIG. 14B

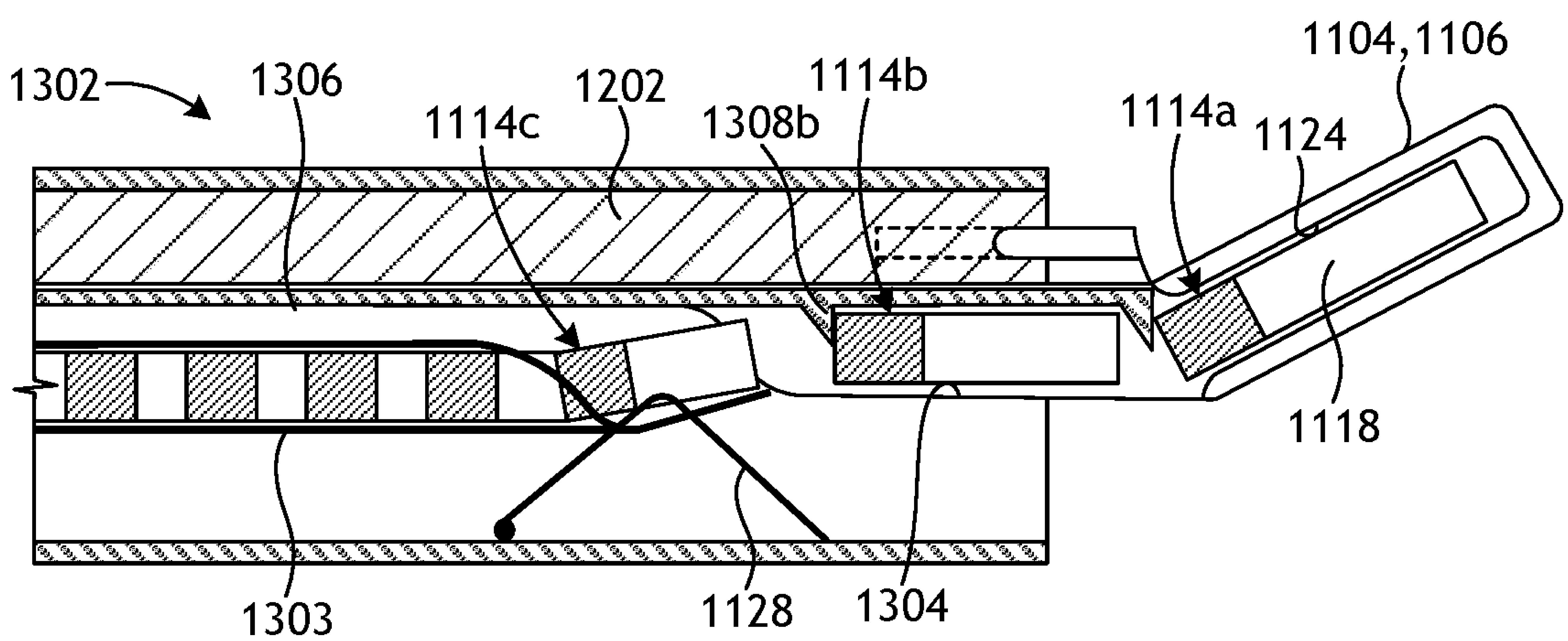

FIG. 14C

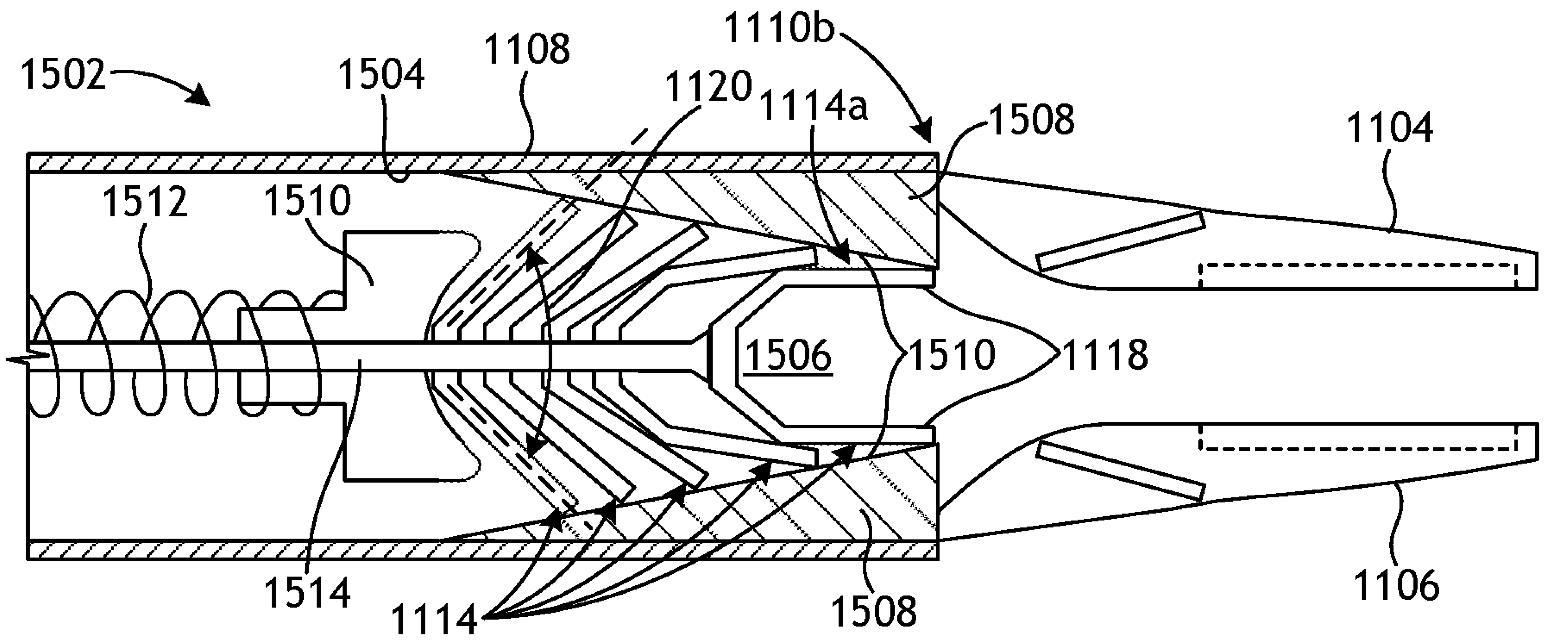

FIG. 15A

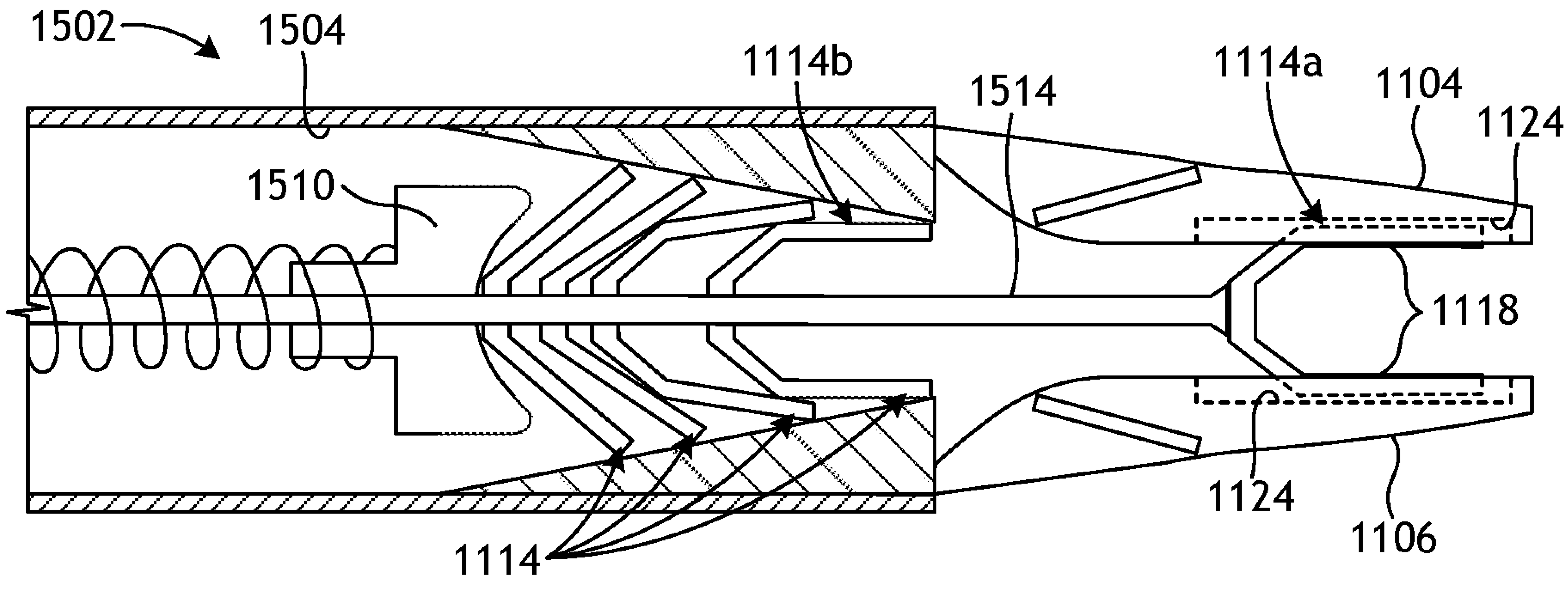

FIG. 15B

SURGICAL CLIP APPLIER WITH WIDE APERTURE SURGICAL CLIPS

BACKGROUND

Minimally invasive surgical (MIS) tools and procedures are often preferred over traditional open surgical approaches due to their propensity toward reducing post-operative recovery time and leaving minimal scarring. Endoscopic surgery is one type of MIS procedure in which a surgical tool operably connected to an elongate shaft is introduced into the body of a patient through a natural bodily orifice. Laparoscopic surgery is a related type of MIS procedure in which a small incision is formed in the abdomen of a patient and a trocar is inserted through the incision to form a surgical access pathway for a surgical tool and elongate shaft. Once located within the abdomen, the surgical tool engages and/or treats tissue in a number of ways to achieve a diagnostic or therapeutic effect. Manipulation and engagement of the surgical tool may take place via various components passing through the elongate shaft.

One surgical instrument commonly used with a trocar is a surgical clip applier, which can be used to ligate blood vessels, ducts, shunts, or portions of body tissue during surgery. Traditional surgical clip appliers have a handle and an elongate shaft extending from the handle. A pair of movable opposed jaws is positioned at the end of the elongate shaft for holding and forming a surgical clip or "ligation clip" therebetween. In operation, a user (e.g., a surgeon or clinician) positions the jaws around the vessel or duct and squeezes a trigger on the handle to close the jaws and thereby collapse the surgical clip over the vessel.

More recently, however, robotic systems have been developed to assist in MIS procedures. Instead of directly engaging a surgical instrument, users are now able to manipulate and engage surgical instruments via an electronic interface communicatively coupled to a robotic manipulator. With the advances of robotic surgery, a user need not even be in the operating room with the patient during the surgery.

Robotic surgical systems are also now capable of utilizing robotically controlled clip appliers. Such clip appliers include features for robotically feeding and forming surgical clips. Advances and improvements to the methods and devices for applying surgical clips to vessels, ducts, shunts, etc. is continuously in demand to make the process more efficient and safe.

BRIEF DESCRIPTION OF THE DRAWINGS

The following figures are included to illustrate certain aspects of the present disclosure, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, without departing from the scope of this disclosure.

FIG. **1** is a block diagram of an example robotic surgical system that may incorporate some or all of the principles of the present disclosure.

FIG. **2** is an isometric top view of an example surgical tool that may incorporate some or all of the principles of the present disclosure.

FIG. **3** is an isometric bottom view of the surgical tool of FIG. **2**.

FIG. **4** is an exploded view of the elongate shaft and the end effector of the surgical tool of FIGS. **2** and **3**.

FIG. **5** is an exposed isometric view of the surgical tool of FIG. **2**.

FIG. **6** is a side view of an example surgical tool that may incorporate some or all of the principles of the present disclosure.

FIG. **7** illustrates potential degrees of freedom in which the wrist of FIG. **1** may be able to articulate (pivot).

FIG. **8** is an enlarged isometric view of the distal end of the surgical tool of FIG. **6**.

FIG. **9** is a bottom view of the drive housing of the surgical tool of FIG. **6**.

FIG. **10** is an isometric exposed view of the interior of the drive housing of the surgical tool of FIG. **6**.

FIGS. **11**A-**11**C are partial cross-sectional top views of a portion of an example end effector.

FIGS. **12**A-**12**C are partial cross-sectional side views of the end effector of FIGS. **11**A-**11**C.

FIGS. **13**A-**13**E are partial cross-sectional top views of a distal portion of another example end effector.

FIGS. **14**A-**14**C are partial cross-sectional side views of the end effector of FIGS. **13**A-**13**E.

FIGS. **15**A and **15**B are partial cross-sectional top views of a distal portion of another example end effector.

DETAILED DESCRIPTION

The present disclosure is related to surgical systems and, more particularly, to surgical clip appliers having an end effector that stores wide angle surgical clips and transitions the wide angle surgical clips to tissue-ready surgical clips ready for crimping between opposed jaw members.

Embodiments discussed herein describe improvements to clip applier end effectors. The end effectors described herein include an elongate body and a clip track provided within the body and containing one or more surgical clips. Each surgical clip includes a crown and a pair of legs extending longitudinally from the crown and diverging from each other at a diverging opening angle. A pre-forming region is provided within the body and arranged to receive and deform the one or more surgical clips from a first state, where the pair of legs diverge at the diverging opening angle, and a second state, where the diverging opening angle is minimized. First and second jaw members are positioned at a distal end of the body and arranged to receive the one or more surgical clips from the pre-forming region in the second state. Storing the surgical clips in the clip track in the first state allows the surgical clips to be arranged in a nested relationship, which decreases the overall length of the end-effector. The pre-forming region is used to transition the surgical clips into the second state or a "tissue-ready" state capable of being received between the jaw members and crimped over tissue as desired.

In contrast to conventional clip appliers, the surgical clips may be received by the jaw members crown first, which helps mitigate catching the surgical clips on any sharp corners that might obstruct their distal advancement. Moreover, the presently described jaw members may comprise independent or separate plate-like structures that may prove advantageous in facilitating parallel closure of the jaw members, which can reduce the force required to crimp a surgical clip.

FIG. **1** is a block diagram of an example robotic surgical system **100** that may incorporate some or all of the principles of the present disclosure. As illustrated, the system **100** can include at least one master controller **102***a* and at least one arm cart **104**. The arm cart **104** may be mechanically and/or electrically coupled to a robotic manipulator and, more particularly, to one or more robotic arms **106** or "tool drivers". Each robotic arm **106** may include and otherwise provide a location for mounting one or more surgical tools or instruments **108** for performing various surgical tasks on a patient **110**. Operation of the robotic arms **106** and instruments **108** may be directed by a clinician **112***a* (e.g., a surgeon) from the master controller **102***a*.

In some embodiments, a second master controller **102***b* (shown in dashed lines) operated by a second clinician **112***b* may also direct operation of the robotic arms **106** and instruments **108** in conjunction with the first clinician **112***a*. In such embodiments, for example, each clinician **102***a,b* may control different robotic arms **106** or, in some cases, complete control of the robotic arms **106** may be passed between the clinicians **102***a,b*. In some embodiments, additional arm carts (not shown) having additional robotic arms (not shown) may be utilized during surgery on a patient **110**, and these additional robotic arms may be controlled by one or more of the master controllers **102***a,b*.

The arm cart **104** and the master controllers **102***a,b* may be in communication with one another via a communications link **114**, which may be any type of wired or wireless telecommunications mean configured to carry a variety of communication signals (e.g., electrical, optical, infrared, etc.) according to any communications protocol.

The master controllers **102***a,b* generally include one or more physical controllers that can be grasped by the clinicians **112***a,b* and manipulated in space while the surgeon views the procedure via a stereo display. The physical controllers generally comprise manual input devices movable in multiple degrees of freedom, and which often include an actuatable handle for actuating the surgical instrument(s) **108**, for example, for opening and closing opposing jaws, applying an electrical potential (current) to an electrode, or the like. The master controllers **102***a,b* can also include an optional feedback meter viewable by the clinicians **112***a,b* via a display to provide a visual indication of various surgical instrument metrics, such as the amount of force being applied to the surgical instrument (i.e., a cutting instrument or dynamic clamping member).

Example implementations of robotic surgical systems, such as the system **100**, are disclosed in U.S. Pat. No. 7,524,320, the contents of which are incorporated herein by reference. The various particularities of such devices will not be described in detail herein beyond that which may be necessary to understand the various embodiments and forms of the various embodiments of robotic surgery apparatus, systems, and methods disclosed herein.

FIG. **2** is an isometric top view of an example surgical tool **200** that may incorporate some or all of the principles of the present disclosure. The surgical tool **200** may be the same as or similar to the surgical instrument(s) **108** of FIG. **1** and, therefore, may be used in conjunction with the robotic surgical system **100** of FIG. **1**. Accordingly, the surgical tool **200** may be designed to be releasably coupled to a robotic arm **106** (FIG. **1**) of a robotic manipulator of the robotic surgical system **100**. Full detail and operational description of the surgical tool **200** is provided in U.S. Patent Pub. 2016/0287252, entitled “Clip Applier Adapted for Use with a Surgical Robot,” the contents of which are hereby incorporated by reference in their entirety.

While the surgical tool **200** is described herein with reference to a robotic surgical system, it is noted that the principles of the present disclosure are equally applicable to non-robotic surgical tools or, more specifically, manually operated surgical tools. Accordingly, the discussion provided herein relating to robotic surgical systems merely encompasses one example application of the presently disclosed inventive concepts.

As illustrated, the surgical tool **200** can include an elongate shaft **202**, an end effector **204** coupled to the distal end of the shaft **202**, and a drive housing **206** coupled to the proximal end of the shaft **202**. The terms “proximal” and “distal” are defined herein relative to a robotic surgical system having an interface configured to mechanically and electrically couple the surgical tool **200** (e.g., the drive housing **206**) to a robotic manipulator. The term “proximal” refers to the position of an element closer to the robotic manipulator and the term “distal” refers to the position of an element closer to the end effector **204** and thus further away from the robotic manipulator. Moreover, the use of directional terms such as above, below, upper, lower, upward, downward, left, right, and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward or upper direction being toward the top of the corresponding figure and the downward or lower direction being toward the bottom of the corresponding figure.

In applications where the surgical tool **200** is used in conjunction with a robotic surgical system (e.g., system **100** of FIG. **1**), the drive housing **206** can include a tool mounting portion **208** designed with features that releasably couple the surgical tool **200** to a robotic arm (e.g., the robotic arms **106** or “tool drivers” of FIG. **1**) of a robotic manipulator. The tool mounting portion **208** may releasably attach (couple) the drive housing **206** to a tool driver in a variety of ways, such as by clamping thereto, clipping thereto, or slidably mating therewith. In some embodiments, the tool mounting portion **208** may include an array of electrical connecting pins, which may be coupled to an electrical connection on the mounting surface of the tool driver. While the tool mounting portion **208** is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

FIG. **3** is an isometric bottom view of the surgical tool **200**. The surgical tool **200** further includes an interface **302** that mechanically and electrically couples the tool mounting portion **208** to a robotic manipulator. In various embodiments, the tool mounting portion **208** includes a tool mounting plate **304** that operably supports a plurality of drive inputs, shown as a first drive input **306***a*, a second drive input **306***b*, and a third drive input **306***c*. While only three drive inputs **306***a-c* are shown in FIG. **3**, more or less than three may be employed, without departing from the scope of the disclosure.

In the illustrated embodiment, each drive input **306***a-c* comprises a rotatable disc configured to align with and couple to a corresponding input actuator (not shown) of a given tool driver. Moreover, each drive input **306***a-c* provides or defines one or more surface features **308** configured to align with mating surface features provided on the corresponding input actuator. The surface features **308** can include, for example, various protrusions and/or indentations that facilitate a mating engagement.

FIG. **4** is an exploded view of one example of the elongate shaft **202** and the end effector **204** of the surgical tool **200** of FIGS. **2** and **3**, according to one or more embodiments. As illustrated, the shaft **202** includes an outer tube **402** that houses the various components of the shaft **202**, which can include a jaw retaining assembly **404**. The jaw retaining assembly **404** includes a jaw retainer shaft **406** with a clip track **408** and a push rod channel **410** formed thereon. The end effector **204** includes opposing jaws **412** that are configured to mate to a distal end of the clip track **408**.

The shaft **202** also includes a clip advancing assembly, which, in one example embodiment, can include a feeder shoe **414** adapted to be slidably disposed within the clip track **408**. The feeder shoe **414** is designed to advance a series of clips **416** positioned within the clip track **408**, and a feedbar **418** is adapted to drive the feeder shoe **414** through the clip track **408**. An advancer assembly **420** is adapted to mate to a distal end of the feedbar **418** for advancing a distal-most clip into the jaws **412**.

The shaft **202** furthers include a clip forming or camming assembly operable to collapse the jaws **412** and thereby crimp (crush) a surgical clip **416** positioned between (interposing) the jaws **412**. The camming assembly includes a cam **422** that slidably mates to the jaws **412**, and a push rod **424** that moves the cam **422** relative to the jaws **412** to collapse the jaws **412**. A tissue stop **426** can mate to a distal end of the clip track **408** to help position the jaws **412** relative to a surgical site.

The jaw retainer shaft **406** is extendable within and couples to the outer tube **402** at a proximal end **428***a*, and its distal end **428***b* is adapted to mate with the jaws **412**. The push rod channel **410** formed on the jaw retainer shaft **406** may be configured to slidably receive the push rod **424**, which is used to advance the cam **422** over the jaws **412**. The clip track **408** extends distally beyond the distal end **428***b* of the jaw retainer shaft **406** to allow a distal end of the clip track **408** to be substantially aligned with the jaws **412**.

The clip track **408** can include several openings **430** formed therein for receiving an upper or "superior" tang **432***a* formed on the feeder shoe **414** adapted to be disposed within the clip track **408**. The clip track **408** can also include a stop tang **434** formed thereon that is effective to be engaged by a corresponding stop tang formed on the feeder shoe **414** to prevent movement of the feeder shoe **414** beyond a distal-most position. To facilitate proximal movement of the feeder shoe **414** within the clip track **408**, the feeder shoe **414** can also include a lower or "inferior" tang **432***b* formed on the underside thereof for allowing the feeder shoe **414** to be engaged by the feedbar **418** as the feedbar **418** is moved distally. In use, each time the feedbar **418** is moved distally, a detent formed in the feedbar **418** engages the inferior tang **432***b* and moves the feeder shoe **414** distally a predetermined distance within the clip track **408**. The feedbar **418** can then be moved proximally to return to its initial position, and the angle of the inferior tang **432***b* allows the inferior tang **432***b* to slide into the next detent formed in the feedbar **418**.

The jaws **412** include first and second opposed jaw members that are movable (collapsible) relative to one another and are configured to receive a surgical clip from the series of clips **416** therebetween. The jaw members can each include a groove formed on opposed inner surfaces thereof for receiving the legs of a surgical clip **416** in alignment with the jaw members. In the illustrated embodiment, the jaw members are biased to an open position and a force is required to urge the jaw members toward one another to crimp the interposing clip **416**. The jaw members can also each include a cam track formed thereon for allowing the cam **422** to slidably engage and move the jaw members toward one another. A proximal end **436***a* of the cam **422** is matable with a distal end **438***a* of the push rod **424**, and a distal end **436***b* of the cam **422** is adapted to engage and actuate the jaws **412**. The proximal end **438***b* of the push rod **424** is matable with a closure link assembly associated with the drive housing **206** for moving the push rod **424** and the cam **422** relative to the jaws **412**.

The distal end **436***b* of the cam **422** includes a camming channel or tapering recess formed therein for slidably receiving corresponding cam tracks provided by the jaw members. In operation, the cam **422** is advanced from a proximal position, in which the jaw members are spaced apart from one another, to a distal position, where the jaw members are collapsed to a closed position. As the cam **422** is advanced over the jaw members, the tapering recess at the distal end **436***b* serves to push the jaw members toward one another, thereby crimping a surgical clip **416** disposed therebetween.

FIG. **5** is an exposed isometric view of the surgical tool **200** of FIG. **2**, according to one or more embodiments. The shroud or covering of the drive housing **206** has been removed to reveal the internal component parts. As illustrated, the surgical tool **200** may include a first drive gear **502***a*, a second drive gear **502***b*, and a third drive gear **502***c*. The first drive gear **502***a* may be operatively coupled to (or extend from) the first drive input **306***a* (FIG. **3**) such that actuation of the first drive input **306***a* correspondingly rotates the first drive gear **502***a*. Similarly, the second and third drive gears **502***b,c* may be operatively coupled to (or extend from) the second and third drive inputs **306***b,c* (FIG. **3**), respectively, such that actuation of the second and third drive inputs **306***b,c* correspondingly rotates the second and third drive gears **502***b,c*, respectively.

The first drive gear **502***a* may be configured to intermesh with a first driven gear **504***a*, which is operatively coupled to the shaft **202**. In the illustrated embodiment, the driven gear **504***a* comprises a helical gear. In operation, rotation of the first drive gear **502***a* about a first axis correspondingly rotates the first driven gear **504***a* about a second axis orthogonal to the first axis to control rotation of the shaft **202** in clockwise and counter-clockwise directions based on the rotational direction of the first drive gear **502***a*.

The second drive gear **502***b* may be configured to intermesh with a second driven gear **504***b* (partially visible in FIG. **5**), and the third drive gear **502***c* may be configured to intermesh with a third driven gear **504***c*. In the illustrated embodiment, the second and third drive and driven gears **502***b,c*, **504***b,c* comprise corresponding rack and pinion interfaces, where the driven gears **504***b,c* comprise the rack and the drive gears **502***b,c* comprise the pinion. Independent rotation of the second and third drive gears **502***b,c* will cause the second and third driven gears **504***b,c*, respectively, to translate linearly relative to (independent of) one another.

In at least one embodiment, actuation (rotation) of the third drive gear **502***c* will result in a surgical clip **416** (FIG. **4**) being fed into the jaws **412**. More particularly, the third driven gear **504***c* may be operatively coupled to the feedbar **418** (FIG. **4**) and, upon rotation of the third drive gear **502***c* in a first angular direction, the third driven gear **504***c* will advance distally and correspondingly advance the feedbar **418** a sufficient distance to fully advance a surgical clip into the jaws **412**. Rotation of the third drive gear **502***c* may be precisely controlled by an electrical and software interface to deliver the exact linear travel to the third driven gear **504***c* necessary to feed a clip **416** into the jaws **412**.

Upon delivery of a clip into the jaws **412**, or after a predetermined amount of rotation of the third drive gear **502***c*, rotation of the third drive gear **502***c* is reversed in a second angular direction to move the third driven gear **504***c* linearly in a proximal direction, which correspondingly moves the feedbar **418** proximally. This process may be repeated several times to accommodate a predetermined number of clips residing in the shaft **202**.

Actuation of the second drive gear **502*b*** causes the jaws **412** to close or collapse to crimp a surgical clip. More particularly, the second driven gear **504*b*** may be coupled to the proximal end **438*b*** (FIG. **4**) of the push rod **424** (FIG. **4**) and, upon actuation of the second drive gear **502*b*** in a first angular direction, the second driven gear **504*b*** will be advanced linearly in a distal direction and correspondingly drive the push rod **424** distally, which drives the cam **422** over the jaws **412** to collapse the jaw members and crimp a surgical clip positioned in the jaws **412**. Once a surgical clip is successfully deployed, rotation of the second drive gear **502*b*** is reversed in the opposite angular direction to move the second driven gear **504*b*** in a proximal direction, which correspondingly moves the push rod **424** and the cam **422** proximally and permits the jaws **412** to open once again.

The processes of delivering a surgical clip into the jaws **412** and collapsing the jaws **412** to crimp the surgical clip are not limited to the actuation mechanisms and structures described herein. In alternative embodiments, for example, the second and third driven gears **504*b,c*** may instead comprise capstan pulleys configured to route and translate drive cables within the shaft **202**. In such embodiments, the drive cables may be operatively coupled to one or more lead screws or other types of rotating members positioned within the shaft **202** near the distal end and capable of advancing the feedbar **418** to deliver a surgical clip into the jaws **412** and advancing the cam **422** to collapse the jaws **412** and crimp the surgical clip.

FIG. **6** is an isometric top view of another example surgical tool **600** that may incorporate some or all of the principles of the present disclosure. Similar to the surgical tool **200** of FIG. **2**, the surgical tool **600** may be used in conjunction with the robotic surgical system **100** of FIG. **1**. As illustrated, the surgical tool **600** includes an elongate shaft **602**, an end effector **604** positioned at the distal end of the shaft **602**, a wrist **606** (alternately referred to as a "articulable wrist joint") that couples the end effector **604** to the distal end of the shaft **602**, and a drive housing **608** coupled to the proximal end of the shaft **602**. In some embodiments, the shaft **602**, and hence the end effector **604** coupled thereto, is configured to rotate about a longitudinal axis A_1.

In the illustrated embodiment, the end effector **604** comprises a clip applier that includes opposing jaw members **610**, **612** configured to collapse toward one another to crimp a surgical clip. The wrist **606** comprises an articulatable joint that facilitates pivoting movement of the end effector **604** relative to the shaft **602** to position the end effector **604** at desired orientations and locations relative to a surgical site. The housing **608** includes (contains) various actuation mechanisms designed to control articulation and operation of the end effector **604**.

FIG. **7** illustrates the potential degrees of freedom in which the wrist **606** may be able to articulate (pivot). The degrees of freedom of the wrist **606** are represented by three translational variables (i.e., surge, heave, and sway), and by three rotational variables (i.e., Euler angles or roll, pitch, and yaw). The translational and rotational variables describe the position and orientation of a component of a surgical system (e.g., the end effector **604**) with respect to a given reference Cartesian frame. As depicted in FIG. **7**, "surge" refers to forward and backward translational movement, "heave" refers to translational movement up and down, and "sway" refers to translational movement left and right. With regard to the rotational terms, "roll" refers to tilting side to side, "pitch" refers to tilting forward and backward, and "yaw" refers to turning left and right.

The pivoting motion can include pitch movement about a first axis of the wrist **606** (e.g., X-axis), yaw movement about a second axis of the wrist **606** (e.g., Y-axis), and combinations thereof to allow for 360° rotational movement of the end effector **604** about the wrist **606**. In other applications, the pivoting motion can be limited to movement in a single plane, e.g., only pitch movement about the first axis of the wrist **606** or only yaw movement about the second axis of the wrist **606**, such that the end effector **604** moves only in a single plane. SURGE

Referring again to FIG. **6**, the surgical tool **600** includes a plurality of drive cables (generally obscured in FIG. **6**) that form part of a cable driven motion system configured to facilitate operation and articulation (movement) of the end effector **604** relative to the shaft **602**. For example, selectively moving the drive cables can actuate the end effector **604** and thereby collapse the jaw members **610**, **612** toward each other. Moreover, moving the drive cables can also move the end effector **604** between an unarticulated position and an articulated position. The end effector **604** is depicted in FIG. **6** in the unarticulated position where a longitudinal axis A_2 of the end effector **604** is substantially aligned with the longitudinal axis A_1 of the shaft **602**, such that the end effector **604** is at a substantially zero angle relative to the shaft **602**. In the articulated position, the longitudinal axes A_1, A_2 would be angularly offset from each other such that the end effector **604** is at a non-zero angle relative to the shaft **602**.

FIG. **8** is an enlarged isometric view of the distal end of the surgical tool **600** of FIG. **6**. More specifically, FIG. **8** depicts an enlarged and partially exploded view of the end effector **604** and the wrist **606**. The wrist **606** operatively couples the end effector **604** to the shaft **602**. To accomplish this, the wrist **606** includes a distal clevis **802*a***, a proximal clevis **802*b***, and a spacer **803** interposing the distal and proximal clevises **802*a,b***. The end effector **604** is coupled to the distal clevis **802*a*** and the distal clevis **802*a*** is rotatably mounted to the spacer **803** at a first axle **804*a***. The spacer **803** is rotatably mounted to the proximal clevis **802*b*** at a second axle **804*b*** and the proximal clevis **802*b*** is coupled to a distal end **806** of the shaft **602**.

The wrist **606** provides a first pivot axis P_1 that extends through the first axle **804*a*** and a second pivot axis P_2 that extends through the second axle **804*b***. The first pivot axis P_1 is substantially perpendicular (orthogonal) to the longitudinal axis A_2 of the end effector **604**, and the second pivot axis P_2 is substantially perpendicular (orthogonal) to both the longitudinal axis A_2 and the first pivot axis P_1. Movement about the first pivot axis P_1 provides "pitch" articulation of the end effector **604**, and movement about the second pivot axis P_2 provides "yaw" articulation of the end effector **604**.

A plurality of drive cables **808** extend longitudinally within the shaft **602** and pass through the wrist **106** to be operatively coupled to the end effector **604**. The drive cables **808** form part of the cable driven motion system briefly described above, and may be referred to and otherwise characterized as cables, bands, lines, cords, wires, ropes, strings, twisted strings, elongate members, etc. The drive cables **808** can be made from a variety of materials including, but not limited to, metal (e.g., tungsten, stainless steel, etc.) or a polymer.

The drive cables **808** extend proximally from the end effector **604** to the drive housing **608** (FIG. **6**) where they are operatively coupled to various actuation mechanisms or devices housed (contained) therein to facilitate longitudinal movement (translation) of the drive cables **808**. Selective actuation of the drive cables **808** causes the end effector **604** to articulate (pivot) relative to the shaft **602**. Moving a given drive cable **808** constitutes applying tension (i.e., pull force) to the given drive cable **808** in a proximal direction, which causes the given drive cable **808** to translate and thereby cause the end effector **604** to move (articulate) relative to the shaft **602**.

One or more actuation cables **810**, shown as first actuation cables **810***a* and second actuation cables **810***b*, may also extend longitudinally within the shaft **602** and pass through the wrist **106** to be operatively coupled to the end effector **604**. The actuation cables **810***a,b* may be similar to the drive cables **808** and also form part of the cable driven motion system. Selectively actuating the actuation cables **810***a,b* causes the end effector **604** to actuate, such as collapsing the first and second jaw members **610**, **612** to crimp a surgical clip (not shown).

More specifically, the actuation cables **810***a,b* may be operatively coupled to a cam **812** that is slidably engageable with the jaw members **610**, **612**. One or more pulleys **814** may be used to receive and redirect the first actuation cables **810***a* for engagement with the cam **812**. Longitudinal movement of the first actuation cables **810***a* correspondingly moves the cam **812** distally relative to the jaw members **610**, **612**. The distal end of the cam **812** includes a tapering recess or camming channel **1204** formed therein for slidably receiving corresponding cam tracks **818** provided by the jaw members **610**, **612**. As the cam **812** is advanced distally, the camming channel **1204** pushes (collapses) the jaw members **610**, **612** toward one another, thereby crimping a surgical clip (not shown) disposed therebetween. Actuation of the second actuation cables **810***b* (one shown) pulls the cam **812** proximally, thereby allowing the jaw members **610**, **612** to open again to receive another surgical clip.

Although not expressly depicted in FIG. **8**, an assembly including, for example, a feedbar, a feeder shoe, and a clip track may be included at or near the end effector **604** to facilitate feeding surgical clips into the jaw members **610**, **612**. In some embodiments, the feedbar (or a connecting member) may be flexible and extend through the wrist **606**.

FIG. **9** is a bottom view of the drive housing **608**, according to one or more embodiments. As illustrated, the drive housing **608** may include a tool mounting interface **902** used to operatively couple the drive housing **608** to a tool driver of a robotic manipulator. The tool mounting interface **902** may mechanically, magnetically, and/or electrically couple the drive housing **608** to a tool driver.

As illustrated, the interface **902** includes and supports a plurality of drive inputs, shown as drive inputs **906***a*, **906***b*, **906***c*, **906***d*, **906***e*, and **906***f*. Each drive input **906***a-f* may comprise a rotatable disc configured to align with and couple to a corresponding input actuator (not shown) of a tool driver. Moreover, each drive input **906***a-f* provides or defines one or more surface features **908** configured to align with mating features provided on the corresponding input actuator. The surface features **908** can include, for example, various protrusions and/or indentations that facilitate a mating engagement.

In some embodiments, actuation of the first drive input **906***a* may control rotation of the elongate shaft **602** about its longitudinal axis A_1. Depending on the rotational actuation of the first drive input **906***a*, the elongate shaft **602** may be rotated clockwise or counter-clockwise. In some embodiments, selective actuation of the second and third drive inputs **906***b,c* may cause movement (axial translation) of the actuation cables **810***a,b* (FIG. **8**), which causes the cam **812** (FIG. **8**) to move and crimp a surgical clip, as generally described above. In some embodiments, actuation of the fourth drive input **906***d* feeds a surgical clip into the jaw members **610**, **612** (FIG. **8**). In some embodiments, actuation of the fifth and sixth drive inputs **906***e,f* causes movement (axial translation) of the drive cables **808** (FIG. **8**), which results in articulation of the end effector **604**. Each of the drive inputs **906***a-f* may be actuated based on user inputs communicated to a tool driver coupled to the interface **902**, and the user inputs may be received via a computer system incorporated into the robotic surgical system.

FIG. **10** is an isometric exposed view of the interior of the drive housing **608**, according to one or more embodiments. Several component parts that may otherwise be contained within the drive housing **608** are not shown in FIG. **10** to enable discussion of the depicted component parts.

As illustrated, the drive housing **608** contains a first capstan **1002***a*, which is operatively coupled to or extends from the first drive input **906***a* (FIG. **9**) such that actuation of the first drive input **906***a* results in rotation of the first capstan **1002***a*. A helical drive gear **1004** is coupled to or forms part of the first capstan **1002***a* and is configured to mesh and interact with a driven gear **1006** operatively coupled to the shaft **602** such that rotation of the driven gear **1006** correspondingly rotates the shaft **602**. Accordingly, rotation of the helical drive gear **1004** (via actuation of the first drive input **906***a* of FIG. **9**) will drive the driven gear **1006** and thereby control rotation of the elongate shaft **602** about the longitudinal axis A_1.

The drive housing **608** also includes second and third capstans **1002***b* and **1002***c* operatively coupled to or extending from the second and third drive inputs **906***b,c* (FIG. **9**), respectively, such that actuation of the second and third drive inputs **906***b,c* results in rotation of the second and third capstans **1002***b,c*. The second and third capstans **1002***b,c* comprise capstan pulleys operatively coupled to the actuation cables **810***a,b* (FIG. **8**) such that rotation of a given capstan **1002***b,c* actuates (longitudinally moves) a corresponding one of the actuation cables **810***a,b*. Accordingly, selective rotation of the second and third capstans **1002***b,c* via actuation of the second and third drive inputs **906***b,c*, respectively, will cause movement (axial translation) of the actuation cables **810***a,b*, which causes the cam **812** (FIG. **8**) to move and crimp a surgical clip.

The drive housing **608** further includes a fourth capstan **1002***d*, which is operatively coupled to or extends from the fourth drive input **906***d* (FIG. **9**) such that actuation of the fourth drive input **906***d* results in rotation of the fourth capstan **1002***d*. A spur gear **1008** is coupled to or forms part of the fourth capstan **1002***d* and is configured to mesh and interact with a rack gear (not shown) also contained within the drive housing **608**. The rack gear may be operatively coupled to a feedbar (or another connecting member) which facilitates operation of a feeder shoe and associated clip track to feed surgical clips into the jaw members **610**, **612** (FIGS. **6** and **8**). Accordingly, rotation of the spur gear **1008** (via actuation of the fourth drive input **906***d*) will control the feedbar and thereby control loading of surgical clips into the jaw members **610**, **612** as desired.

The drive housing **608** further contains or houses fifth and sixth capstans **1002***e* and **1002***f* operatively coupled to or extending from the fifth and sixth drive inputs **906***e,f* (FIG. **9**), respectively, such that actuation of the fifth and sixth drive inputs **906***e,f* results in rotation of the fifth and sixth capstans **1002***e,f*. The fifth and sixth capstans **1002***e,f* comprise capstan pulleys operatively coupled to the drive cables **808** (FIG. **8**) such that rotation of a given capstan **1002***e,f* actuates (longitudinally moves) a corresponding one of the actuation cables **808**. Accordingly, selective rotation of the fifth and sixth capstans **1002***e,f* via actuation of the fifth and sixth drive inputs **906***e,f*, respectively, will cause movement (axial translation) of the drive cables **808** and thereby articulate (pivot) the end effector **604** relative to the shaft **602**.

The surgical tools **200**, **600** described herein above may incorporate and facilitate the principles of the present disclosure in improving feeding and/or forming of surgical clips in robotic or non-robotic clip appliers. Moreover, it is contemplated herein to combine some or all of the features of the surgical tools **200**, **600** to facilitate operation of the embodiments described below. Accordingly, example surgical tools that may incorporate the principles of the present disclosure may include geared actuators, capstan pulley and cable actuators, or any combination thereof, without departing from the scope of the disclosure.

FIGS. **11A-11C** are partial cross-sectional top views of a distal portion of an example end effector **1102**, according to one or more embodiments of the present disclosure. The end effector **1102** may be similar in some respects to the end effectors **204** and **604** of FIGS. **2** and **6**, respectively. For instance, similar to the end effectors **204**, **604**, the end effector **1102** may be incorporated into either or both of the surgical tools **200**, **600** described herein above. Moreover, the end effector **1102** may comprise a clip applier having opposed jaw members **1104** and **1106** actuatable to collapse toward one another to crimp a surgical clip. As described herein, the end effector **1102** may incorporate various component parts and actuatable mechanisms or features that facilitate the feeding of surgical clips into the jaw members **1104**, **1106** and collapsing the jaw members **1104**, **1106** to crimp the surgical clip when desired.

FIGS. **11A-11C** illustrate progressive views of the end effector **1102** during example operation of feeding the surgical clips **1114** into the jaw members **1104**, **1106**. Referring first to FIG. **11A**, the end effector **1102** includes an elongate body **1108** having a proximal end **1110***a* and a distal end **1110***b*. In some embodiments, the body **1108** may be the same as or similar to the outer tube **402** of FIG. **4**. In other embodiments, however, the body **1108** may comprise an independent structure from the outer tube **402**. Various component parts and mechanisms of the end effector **1102** are positioned within the inside or interior of the body **1108**. The jaw members **1104**, **1106** extend out of or otherwise protrude from the distal end **1110***b* of the body **1108**. In at least one embodiment, the proximal end **1110***a* may be operatively coupled to an elongate shaft of a surgical tool, such as the shaft **202** of the surgical tool **200** of FIG. **2**. In other embodiments, however, the proximal end **1110***a* may be operatively coupled to an articulable wrist joint, such as the wrist **606** of the surgical tool **600** of FIG. **6**. In such embodiments, the surgical clips **1114** are stored distal to the wrist within the end effector **1102**.

The end effector **1102** also includes a clip track **1112**. In some embodiments, the body **1108** defines or otherwise provides the clip track **1112**. In other embodiments, however, the clip track **1112** may comprise a separate structural component that is removably positioned within the body **1108**. The clip track **1112** may be configured to contain and otherwise house one or more surgical clips **1114**, and preferably a plurality of surgical clips **1114** arranged in series. While four surgical clips **1114** are depicted in FIG. **11A**, more or less than four may be employed, without departing from the scope of the disclosure.

Each surgical clip **1114** includes a crown **1116** (alternately referred to as an "apex") and a pair of legs **1118** extending longitudinally from the crown **1116**. The legs of conventional surgical clips typically converge toward one another. Converging legs, however, reduce the clip-to-jaw retention capability and also reduce allowable tip width between the jaw members **1104**, **1106**, which correspondingly limits the size of tissue that can be treated with the end effector **1102**. Moreover, with converging clip legs, the surgical clips are commonly arranged with the legs of the more proximal surgical clips engaging the crown of the more distal surgical clips, which maximizes the axial space accommodated by the surgical clips in the clip track and thereby reduces the number of clips that can be stored for use.

In contrast, the surgical clips **1114** described herein may be characterized as "wide-aperture" surgical clips. More specifically, the legs **1118** of the surgical clips **1114** diverge from each other and otherwise open to a diverging opening angle **1120** relative to one another. The diverging opening angle **1120** may comprise any angle that results in the legs **1118** diverging from each other as extending from the crown **1116**. The diverging opening angle **1120** may range between about 5° and about 35°, but could be as large as 45° or more, depending on the design constraints of the clip track **1112**.

The diverging opening angle **1120** may prove advantageous in allowing the surgical clips **1114** to be positioned within the clip track **1112** in a partially or fully nested configuration, where the legs **1118** of the more proximal surgical clips **1114** extend past the crown **1116** and partially overlap the legs **1118** of the more distal surgical clips **1114**. Consequently, the more distal surgical clips **1114** are received by and partially nested within the more proximal distal clips **1114**. As will be appreciated, this nested configuration allows the clip track **1112** to accommodate a higher number of surgical clips **1114** within the same axial constraints (dimensions), which provides a user with additional surgical clips **1114** for use.

Surgical clips **1114** with legs **1118** that diverge at the diverging opening angle **1120** are referred to herein as being in a first or "wide" state. To be received between the jaw members **1104**, **1106** for crimping, however, the surgical clips **1114** must be transitioned from the wide state to a second or "tissue-ready" state. To accomplish this, the end effector **1102** may include a pre-forming region **1122** configured to receive wide state surgical clips **1114** and reduce (minimize) the diverging opening angle **1120** as the surgical clips **1114** advance distally such that tissue ready surgical clips **1114** are discharged into the jaw members **1104**, **1106**. The surgical clips **1114** may be plastically or elastically deformed as they traverse the pre-forming region **1122** in the distal direction. The surgical clips **1114** are fully formed when the jaw members **1104**, **1106** collapse and crimp the surgical clips **1114**.

As used herein, "minimizing" the diverging opening angle **1120** refers to decreasing the diverging opening angle **1120** to an angular magnitude where the surgical clip **1114** can be received in between the jaw members **1104**, **1106**. In at least one embodiment, "minimizing" the diverging opening angle **1120** refers to eliminating the diverging opening angle **1120** such that the legs **1118** extend parallel or substantially parallel to one another.

The pre-forming region **1122** generally comprises opposed structural surfaces that converge or taper toward one another in the distal direction. In some embodiments, the pre-forming region **1122** may be defined by the body **1108**. In other embodiments, however, the pre-forming region **1122** may be defined or otherwise provided by the clip track **1112**.

The distal end of the pre-forming region **1122** may be aligned with and arranged to feed tissue-ready surgical clips

1114 into the jaw members **1104**, **1106**. In at least one embodiment, each jaw member **1104**, **1106** includes a channel or groove **1124** formed on opposed inner surfaces thereof for receiving a distal-most surgical clip, referenced herein as **1114***a*. In such embodiments, the grooves **1124** may prove advantageous in helping to capture and maintain the distal-most surgical clip **1114***a* in a known and secure position between the jaw members **1104**, **1106**. In other embodiments, however, the grooves **1124** may be omitted and the distal-most surgical clip **1114***a* may instead be captured or held between the jaw members **1104**, **1106** via an interference fit or the like.

The end effector **1102** may further include a feedbar **1126**, a retention member **1128**, and a feeder shoe **1130**. The feedbar **1126** may be configured to engage and move the distal-most surgical clip **1114***a* through the pre-forming region **1122** and deliver the distal-most surgical clip **1114** in its tissue-ready state to the jaw members **1104**, **1106**. In some embodiments, the feedbar **1126** may extend to the end effector **1102** from a drive housing (e.g., the drive housings **206**, **606** of FIGS. **2** and **6**, respectively). At the drive housing, the feedbar **1126** may be operatively coupled to an actuating mechanism or device configured to cause longitudinal translation of the feedbar **1126**. In one embodiment, for example, the feedbar **1126** may be operatively coupled to and otherwise extend from one or more translatable driven gears, such as the first and second driven gears **504***a,b* of FIG. **5**. In embodiments with an articulable wrist, the feedbar **1126** may be made of a flexible material and extend through the wrist. Alternatively, the feedbar **1126** may be operatively coupled to a cable-driven worm gear arranged distal to the wrist and the associated drive cable(s) that moves the worm gear extend through the wrist.

The retention member **1128** may be configured to engage the distal-most surgical clip **1114***a* and thereby prevent the stacked surgical clips **1114** from advancing distally until the distal-most surgical clip **1114***a* is acted upon by the feedbar **1126**. In some embodiments, the retention member **1128** may comprise a passive biasing device, such as a gate spring or the like. In such embodiments, the spring force of the retention member **1128** may be sufficient to retain the stacked surgical clips **1114** in place, but may be overcome when the feedbar **1126** applies an axial load on the distal-most surgical clip **1114***a*. In other embodiments, however, the retention member **1128** may comprise a post or the like operatively coupled to an actuatable device or mechanism. The post may be configured to retain the stacked surgical clips **1114** in place and release the distal-most surgical clip **1114***a* when actuated. In such embodiments, the retention member **1128** may be actuated and otherwise driven using any of the actuation components associated with the drive housings **206**, **606** (FIGS. **2** and **6**, respectively) discussed herein, or alternatively may be operatively coupled to a cable-driven worm gear or the like arranged near the end effector **1102**.

The feeder shoe **1130** may be configured to apply an axial load in the distal direction on the surgical clips **1114** positioned within the clip track **1112**. The axial load helps maintain proper positioning and sequential feeding of the surgical clips **1114**. In some embodiments, as illustrated, the feeder shoe **1130** may include a compression spring **1132** that engages a proximal end of the feeder shoe **1130** to provide a passive and constant axial load on the surgical clips **1114**. In other embodiments, however, the feeder shoe **1130** may include or comprise an actuatable device or mechanism that selectively supplies the axial load. In such embodiments, the feeder shoe **1130** may apply the axial load only to advance the surgical clips **1114** a predetermined distance within the clip track **1112**.

With additional reference to FIGS. **11**B and **11**C, example operation of feeding the distal-most surgical clip **1114***a* into the jaw members **1104**, **1106** is now provided. In FIG. **11**A, the retention member **1128** is shown engaging the distal-most surgical clip **1114***a* and thereby preventing the stacked surgical clips **1114** from advancing distally until acted upon by the feedbar **1126**. In some embodiments, as illustrated, the retention member **1128** may engage the distal-most surgical clip **1114***a* at or near the crown **1116**. In other embodiments, however, the retention member **1128** may engage the distal-most surgical clip **1114***a* at any other location or may alternatively engage the entire stack of surgical clips **1114**, without departing from the scope of the disclosure.

To advance the distal-most surgical clip **1114***a* toward the jaw members **1104**, **1106**, the feedbar **1126** may be advanced distally until engaging the distal-most surgical clip **1114***a*. In some embodiments, as illustrated, the feedbar **1126** may engage the distal-most surgical clip **1114***a* at or near the crown **1116**, but could alternatively engage the distal-most surgical clip **1114***a* at any other location. In embodiments where the retention member **1128** comprises a passive spring, an axial load provided by the feedbar **1126** on the distal-most surgical clip **1114***a* may overcome the spring force of the retention member **1128** to bypass the retention member **1128** and thereby move the distal-most surgical clip **1114***a* distally. In other embodiments, however, the retention member **1128** may be actuated or otherwise moved to allow the feedbar **1126** to convey the distal-most surgical clip **1114***a* distally past the retention member **1128**.

In FIG. **11**B, the distal-most surgical clip **1114***a* is shown being advanced distally by the feedbar **1126** past the retention member **1128** and into the pre-forming region **1122**. Once the distal-most surgical clip **1114***a* bypasses the retention member **1128**, the feeder shoe **1130** may distally advance the remaining surgical clips **1114** positioned within the clip track **1112** until a penultimate surgical clip **1114***b* is received and retained by the retention member **1128**. In some embodiments, the compression spring **1132** may provide the required axial load to move the surgical clips **1114** distally, but in other embodiments, the feeder shoe **1130** may be actuated to advance the surgical clips **1114** a predetermined distance.

As the distal-most surgical clip **1114***a* is advanced distally, the legs **1118** are received by and slidably engage the inner walls of the pre-forming region **1122**. The distally converging and ramped configuration of the pre-forming region **1122** transitions the distal-most surgical clip **1114***a* from the first or "wide" state to the second or "tissue-ready" state in preparation for being received by the jaw members **1104**, **1106**. As it traverses the pre-forming region **1122**, the distal-most surgical clip **1114***a* plastically or elastically deforms as the diverging opening angle **1120** (FIG. **11**A) of the legs **1118** is reduced or minimized.

In FIG. **11**C, the distal-most surgical clip **1114***a* is shown as having traversed the pre-forming region **1122** and being received within the jaw members **1104**, **1106**. In embodiments including the grooves **1124** defined on each jaw member **1104**, **1106**, the legs **1118** may spring outward and seat themselves within the grooves **1124**, which may help retain the surgical clip **1114** in place. Otherwise, the distal-most surgical clip **1114** may be retained between the jaw members **1104**, **1106** via an interference. At this point, the jaw members **1104**, **1106** may be actuated to collapse or close and thereby crimp the distal-most surgical clip **1114***a* therebetween. As used herein, "actuating" the jaw members **1104**, **1106** refers to the mechanical process of collapsing or closing the jaw members **1104**, **1106**.

FIGS. **12**A-**12**C are partial cross-sectional side views of the end effector **1102** of FIGS. **11**A-**11**C. Similar to FIGS. **11**A-**11**C, FIGS. **12**A-**12**C provide progressive views of the end effector **1102** during example operation of feeding the distal-most surgical clip **1114***a* into the jaw members **1104**, **1106**.

Referring first to FIG. **12**A, the end effector **1102** may further include a cam **1202** that is slidably engageable with the jaw members **1104**, **1106**. In the illustrated embodiment, the cam **1202** is arranged within the body **1108**, but can alternatively be arranged external to the body **1108**, without departing from the scope of the disclosure. The cam **1202** may be movable relative to the body **1108** and, more importantly, to the jaw members **1104**, **1106**. The distal end of the cam **1202** includes a tapering recess or camming channel **1204** formed therein for slidably receiving corresponding cam tracks **1206** provided by each jaw member **1104**, **1106**. As the cam **1202** is actuated and advanced distally, the camming channel **1204** slidably engages the cam tracks **1206** provided and thereby pushes (collapses) the jaw members **1104**, **1106** toward one another.

As illustrated, the surgical clips **1114** are shown arranged within the clip track **1112** with the distal-most surgical clip **1114***a* at least partially nested within the penultimate surgical clip **1114***b*. Moreover, the retention member **1128** is depicted as engaging the distal-most surgical clip **1114***a* to prevent the stacked surgical clips **1114** from advancing distally. In the illustrated embodiment, the retention member **1128** is depicted as a passive gate spring that engages the distal-most surgical clip **1114***a* at or near its crown **1116**. The retention member **1128** exhibits a spring force sufficient to retain the stacked surgical clips **1114** in place until the distal-most surgical clip **1114***a* is acted upon by the feedbar **1126**.

In some embodiments, the feedbar **1126** may provide or otherwise define a protrusion **1208** at its distal end configured to mate with a groove **1210** defined in the clip track **1112** or the body **1108**. Applying an axial load in the distal direction on the feedbar **1126** disengages the protrusion **1208** from the groove **1210**, following which the feedbar **1126** may be advanced distally until engaging the distal-most surgical clip **1114***a*.

In FIG. **12**B, the distal-most surgical clip **1114***a* is shown being advanced distally by the feedbar **1126** within the clip track **1112** and past the retention member **1128**. More specifically, once the protrusion **1208** exits the groove **1210**, the protrusion **1208** slidably engages the inner wall of the clip track **1112** and causes the distal end of the feedbar **1126** to flex downward and into engagement with the distal-most surgical clip **1114***a*. In the illustrated embodiment, the feedbar **1126** applies an axial load on the distal-most surgical clip **1114***a* that causes the retention member **1128** to flex downward and out of the way. As the distal-most surgical clip **1114***a* is advanced distally, the legs **1118** are received by and slidably engage the inner (lateral) walls of the pre-forming region **1122**, which transitions the distal-most surgical clip **1114***a* from the wide state to the tissue-ready state in preparation for being received by the jaw members **1104**, **1106**.

In FIG. **12**C, after the distal-most surgical clip **1114***a* bypasses the retention member **1128**, the feeder shoe **1130** (FIGS. **11**A-**11**C) may operate to advance the remaining surgical clips **1114** distally within the clip track **1112** until the penultimate surgical clip **1114***b* is received and retained by the retention member **1128**. The distal-most surgical clip **1114***a* is shown in FIG. **12**C as having traversed the pre-forming region **1122** and advanced into the jaw members **1104**, **1106**. In embodiments including the grooves **1124** defined on each jaw member **1104**, **1106**, the legs **1118** may spring outward and seat themselves within the grooves **1124**. With the distal-most surgical clip **1114***a* properly seated within the jaw members **1104**, **1106**, the cam **1202** may then be actuated to collapse the jaw members **1104**, **1106** and thereby crimp the distal-most surgical clip **1114***a* therebetween, as generally described above.

FIGS. **13**A-**13**E are partial cross-sectional top views of a distal portion of another example end effector **1302**, according to one or more embodiments of the present disclosure. The end effector **1302** may be similar in some respects to the end effector **1102** of FIGS. **11**A-**11**C and, therefore, may be best understood with reference thereto, where like numerals will correspond to like components not described again in detail. FIGS. **13**A-**13**E illustrate progressive views of the end effector **1302** during example operation of feeding surgical clips **1114** into the jaw members **1104**, **1106** for crimping.

Referring first to FIG. **13**A, the end effector **1302** includes the elongate body **1108** and the jaw members **1104**, **1106** extend out of or otherwise protrude from the distal end **1110***b* thereof. A clip track **1303** is arranged within the body **1108** and is configured to contain and otherwise house the surgical clips **1114**. While six surgical clips **1114** are depicted in FIG. **13**A, more or less than six may be employed, without departing from the scope of the disclosure.

As with the prior embodiment, the legs **1118** of the surgical clips **1114** diverge from each other at the diverging opening angle **1120**. However, the diverging opening angle **1120** depicted in FIG. **13**A is greater than the diverging opening angle **1120** of FIG. **11**A. Consequently, more surgical clips **1114** may be accommodated within the limited axial constraints (dimensions) of the clip track **1303** as the surgical clips **1114** are able to be positioned in a more nested configuration as compared with the surgical clips **1114** of FIGS. **11**A-**11**C.

To transition the distal-most surgical clip **1114***a* from the first or "wide" state to the second or "tissue-ready" state, the distal-most surgical clip **1114***a* may be advanced into a pre-forming region **1304** configured to reduce (minimize) the diverging opening angle **1120** such that the distal-most surgical clip **1114***a* is provided to the jaw members **1104**, **1106** in its tissue-ready state. As illustrated, the pre-forming region **1304** may be provided or otherwise defined by the jaw members **1104**, **1106**. More specifically, the pre-forming region **1304** may be arranged proximal to the distal end of the jaw members **1104**, **1106** and may be characterized as or otherwise form part of a first stage that plastically or elastically deforms the distal-most surgical clip **1114***a* from the wide state to the tissue-ready state. The distal-most surgical clip **1114***a* is then advanced distally into the jaw members **1104**, **1106** and to a second stage where it may be crimped when the jaw members **1104**, **1106** collapse (close) toward one another. The pre-forming region **1304** may be aligned with and arranged to feed tissue-ready surgical clips **1114** into the jaw members **1104**, **1106**, each of which may include the channel or groove **1124** formed on opposed inner surfaces thereof.

The end effector **1302** further includes a feedbar **1306**, which may comprise a two-stage feedbar configured to simultaneously engage and move the distal-most surgical clip **1114***a* and the penultimate surgical clip **1114***b*. To accomplish this, the feedbar **1306** provides a first engagement member **1308***a* and a second engagement member **1308***b*, alternately referred to as distal and proximal teeth, respectively. As illustrated, the first engagement member **1308***a* is located at the distal end of the feedbar **1306** and the second engagement member **1308***b* is located proximal to the first engagement member **1308***a* and axially offset therefrom a predetermined distance. As described below, the first and second engagement members **1308***a,b* may be configured to cooperatively and sequentially advance the distal-most and penultimate surgical clips **1114***a,b* into the pre-forming region **1304** and the jaw members **1104**, **1106** in a two stage process.

The end effector **1302** may also include the retention member **1128**, and the feeder shoe **1130**, which operate as generally described above.

With additional reference to FIGS. **13**B-**13**E, example operation of feeding the surgical clips **1114** into the jaw members **1104**, **1106** is now provided. In FIG. **13**A, the retention member **1128** is shown engaging the distal-most surgical clip **1114***a* and thereby preventing the stacked surgical clips **1114** from advancing distally. To distally advance the distal-most surgical clip **1114***a*, the feedbar **1306** may be advanced until the first engagement member **1308***a* engages the distal-most surgical clip **1114***a*. In embodiments where the retention member **1128** comprises a passive spring, an axial load provided by the feedbar **1306** on the distal-most surgical clip **1114***a* may overcome the spring force of the retention member **1128** to move the distal-most surgical clip **1114***a* distally and into the pre-forming region **1304**. In other embodiments, however, the retention member **1128** may be actuated or otherwise moved to allow the feedbar **1306** to distally move the distal-most surgical clip **1114***a*.

In FIG. **13**B, the distal-most surgical clip **1114***a* is shown as having advanced distally past the retention member **1128** and into the pre-forming region **1304**. Once the distal-most surgical clip **1114***a* bypasses the retention member **1128**, the feeder shoe **1130** may operate to distally advance the remaining surgical clips **1114** positioned within the clip track **1303** until the penultimate surgical clip **1114***b* is received and retained by the retention member **1128**. In some embodiments, advancing the distal-most surgical clip **1114***a* into the pre-forming region **1304** may also advance the second engagement member **1308***b* of the feedbar **1306** into engagement with the penultimate surgical clip **1114***b* as retained by the retention member **1128**.

The distal-most surgical clip **1114***a* is received into the pre-forming region **1304** in its wide state. To transition the distal-most surgical clip **1114***a* to its tissue-ready state, the jaw members **1104**, **1106** may be actuated and otherwise collapsed toward each other. In some embodiments, this may be accomplished through the use of a cam (e.g., the cam **1202** of FIGS. **12**A-**12**C; see also FIGS. **14**A-**14**C) that is slidably engageable with the jaw members **1104**, **1106** and, more particularly, with corresponding cam tracks **1310** provided by the jaw members **1104**, **1106**. As the cam is advanced distally relative to the jaw members **1104**, **1106**, the cam engages the cam tracks **1310** and correspondingly pushes (collapses) the jaw members **1104**, **1106** toward one another.

In FIG. **13**C, the jaw members **1104**, **1106** are depicted as having collapsed or closed toward one another. As the jaw members **1104**, **1106** close, the distal-most surgical clip **1114***a* is partially crimped within the pre-forming region **1304** and otherwise plastically or elastically transitioned from the wide state to the tissue-ready state. The jaw members **1104**, **1106** may then be re-opened to receive the distal-most surgical clip **1114***a* in its tissue-ready state. Accordingly, as illustrated, when the jaw members **1104**, **1106** are actuated for the first time, the pre-forming region **1304** provides a cavity or space that deforms the distal-most surgical clip **1114***a* into its tissue-ready state.

In FIG. **13**D, the distal-most surgical clip **1114***a* is shown as having traversed the pre-forming region **1304** and received by the jaw members **1104**, **1106** as the feedbar **1306** advances distally. In embodiments including the grooves **1124** defined on each jaw member **1104**, **1106**, the legs **1118** of the distal-most surgical clip **1114***a* may spring outward and seat themselves within the grooves **1124**, which helps retain the distal-most surgical clip **1114***a* in place.

As the feedbar **1306** conveys the distal-most surgical clip **1114***a* into the jaw members **1104**, **1106**, the penultimate surgical clip **1114***b* may also be simultaneously conveyed into the pre-forming region **1304** as engaged by the second engagement member **1308***b*. More specifically, the penultimate surgical clip **1114***b* may be advanced distally by advancing the feedbar **1306** and providing an axial load on the penultimate surgical clip **1114***b* at the second engagement member **1308***b*. The axial load transferred to the penultimate surgical clip **1114***b* may overcome the spring force of the retention member **1128** to move the penultimate surgical clip **1114***b* distally and into the pre-forming region **1304**. In other embodiments, however, the retention member **1128** may be actuated or otherwise moved to allow the feedbar **1306** to distally move the penultimate surgical clip **1114***b*.

After the penultimate surgical clip **1114***b* bypasses the retention member **1128**, the feeder shoe **1130** may operate to advance the remaining surgical clips **1114** distally within the clip track **1303** until an antepenultimate surgical clip **1114***c* is received and retained by the retention member **1128**.

The penultimate surgical clip **1114***b* is received into the pre-forming region **1304** in its wide state, and may be transitioned to its tissue-ready state in the same process described above to transition the distal-most surgical clip **1114***a* to the tissue-ready state. Collapsing or closing the jaw members **1104**, **1106** a second time, however, will also crimp the distal-most surgical clip **1114***a* received between the jaw members **1104**, **1106**.

In FIG. **13**E, the jaw members **1104**, **1106** are depicted as having collapsed or closed toward one another a second time. As the jaw members **1104**, **1106** close for the second time, the distal-most surgical clip **1114***a* is crimped between the jaw members **1104**, **1106** and the penultimate surgical clip **1114***b* is simultaneously partially crimped within the pre-forming region **1304** and otherwise transitioned from the wide state to the tissue-ready state. At this point, the jaw members **1104**, **1106** may then be re-opened and the penultimate surgical clip **1114***b* may be advanced distally to be received by the jaw members **1104**, **1106**. Prior to closing the jaw members **1104**, **1106** the second time, the feedbar **1306** may be retracted to engage the first engagement member **1308***a* on the penultimate surgical clip **1114***b*, and the second engagement member **1308***b* may be engaged with the antepenultimate surgical clip **1114***c*.

Accordingly, to operate the end effector **1302**, a user may be required to "prime" the device by advancing surgical clips **1114** twice prior to being able to crimp the distal-most surgical clip **1114***a* between the jaw members **1104**, **1106**. Once properly primed, however, the end effector **1302** will function by crimping the distal-most surgical clip **1114***a* each time the device is fired, and the penultimate and antepenultimate surgical clips **1114***b,c* are automatically advanced and fed through the same process.

FIGS. **14**A-**14**C are partial cross-sectional side views of the end effector **1302** of FIGS. **13**A-**13**E. Similar to FIGS. **13**A-**13**E, FIGS. **14**A-**14**C provide progressive views of the end effector **1302** during example operation of feeding the surgical clips **1114** into the jaw members **1104**, **1106** for forming and crimping in the two-stage process.

Referring first to FIG. **14**A, the end effector **1302** may further include the cam **1202** that is slidably engageable with the jaw members **1104**, **1106**. Again, the cam **1202** may be arranged within the body **1108**, but can alternatively be arranged external to the body **1108**, and the distal end of the cam **1202** includes the tapering recess or camming channel **1204** formed therein for slidably receiving the corresponding cam tracks **1310** provided by the jaw members **1104**, **1106**. As the cam **1202** is actuated and advanced distally, the camming channel **1204** slidably engages the cam tracks **1310** and thereby pushes (collapses) the jaw members **1104**, **1106** toward one another and toward a closed position.

As illustrated, the surgical clips **1114** are shown arranged within the clip track **1303** and at least partially nested within each other, as described above. Moreover, the retention member **1128** is depicted as engaging the distal-most surgical clip **1114***a* to prevent the stacked surgical clips **1114** from further advancing distally. In the illustrated embodiment, the retention member **1128** is depicted as a passive gate spring that engages the distal-most surgical clip **1114***a*. The retention member **1128** exhibits a spring force sufficient to retain the stacked surgical clips **1114** in place until the distal-most surgical clip **1114***a* is acted upon by the feedbar **1306**.

In some embodiments, the distal end of the clip track **1303** may provide or otherwise define a ramped portion **1402**. The ramped portion **1402** may be configured to reposition (elevate) the surgical clips **1114** to enable the first and second engagement members **1308***a,b* of the feedbar **1306** to engage and distally advance the surgical clips **1114** positioned on the ramped portion **1402**. The retention member **1128** may extend through the ramped portion **1402** to retain the surgical clip **1114** positioned thereon and thereby retain the remaining surgical clips **1114** within the clip track **1303**.

To advance the distal-most surgical clip **1114***a* distally, the feedbar **1306** may be advanced until the first engagement member **1308***a* engages the distal-most surgical clip **1114***a*, which is positioned on the ramped portion **1402**. In the illustrated embodiment, the feedbar **1306** applies an axial load that urges the distal-most surgical clip **1114***a* against the retention member **1128**, which flexes downward and out of the way, and thereby allows the distal-most surgical clip **1114***a* to exit the clip track **1303** and enter the pre-forming region **1304**.

In FIG. **14**B, the distal-most surgical clip **1114***a* is shown being advanced distally by the feedbar **1306** and into the pre-forming region **1304**. Once the distal-most surgical clip **1114***a* bypasses the retention member **1128**, the feeder shoe **1130** (FIGS. **13**A-**13**E) distally advances the remaining surgical clips **1114** positioned within the clip track **1303** until the penultimate surgical clip **1114***b* is received and retained by the retention member **1128**. In at least one embodiment, advancing the distal-most surgical clip **1114***a* into the pre-forming region **1304** may also advance the second engagement member **1308***b* of the feedbar **1306** into engagement with the penultimate surgical clip **1114***b*. In other embodiments, however, the second engagement member **1308***b* does not engage the penultimate surgical clip **1114***b* when the distal-most surgical clip **1114***a* is advanced into the pre-forming region **1304**.

While in the pre-forming region **1304**, the distal-most surgical clip **1114***a* may be transitioned from its wide state to its tissue-ready state. As discussed above, this may be accomplished by actuating the cam **1202** to collapse or close the jaw members **1104**, **1106**. As the cam **1202** is advanced distally relative to the jaw members **1104**, **1106**, the camming channel **1204** engages the cam tracks **1310** and correspondingly pushes (collapses) the jaw members **1104**, **1106** toward one another. As the jaw members **1104**, **1106** close, the distal-most surgical clip **1114***a* is partially crimped within the pre-forming region **1304** and otherwise plastically or elastically transitioned from the wide state to the tissue-ready state. The jaw members **1104**, **1106** may then be re-opened to receive the tissue-ready distal-most surgical clip **1114***a*.

In FIG. **14**C, the distal-most surgical clip **1114***a* is shown as having traversed the pre-forming region **1304** and advanced into the jaw members **1104**, **1106**. In embodiments including the grooves **1124** defined on each jaw member **1104**, **1106**, the legs **1118** may spring outward and seat themselves within the grooves **1124**.

As the feedbar **1306** conveys the distal-most surgical clip **1114***a* into the jaw members **1104**, **1106**, the penultimate surgical clip **1114***b* is simultaneously conveyed into the pre-forming region **1304** as engaged by the second engagement member **1308***b*. Applying an axial load on the penultimate surgical clip **1114***b* at the second engagement member **1308***b* may overcome the spring force of the retention member **1128** to move the penultimate surgical clip **1114***b* distally and into the pre-forming region **1304**.

After the penultimate surgical clip **1114***b* bypasses the retention member **1128**, the feeder shoe **1130** (FIGS. **13**A-**13**E) may again operate to advance the remaining surgical clips **1114** distally within the clip track **1303** until an antepenultimate surgical clip **1114***c* is received and retained by the retention member **1128**.

The penultimate surgical clip **1114***b* is received into the pre-forming region **1304** in its wide state, and may be transitioned to its tissue-ready state in the same process described above to transition the distal-most surgical clip **1114***a* to the tissue-ready state. More particularly, the jaw members **1104**, **1106** may once again be closed through operation of the cam **1202**, which partially crimps the penultimate surgical clip **1114***b* within the pre-forming region **1304** and transitions the penultimate surgical clip **1114***b* from the wide state to the tissue-ready state.

Collapsing or closing the jaw members **1104**, **1106** the second time, however, will also crimp the distal-most surgical clip **1114***a* received between the jaw members **1104**, **1106**. At this point, the jaw members **1104**, **1106** may then be re-opened and the penultimate surgical clip **1114***b* may be advanced distally to be received by the jaw members **1104**, **1106**. Prior to closing the jaw members **1104**, **1106** the second time, the feedbar **1306** may be retracted to engage the first engagement member **1308***a* on the penultimate surgical clip **1114***b*, and the second engagement member **1308***b* may be engaged with the antepenultimate surgical clip **1114***c*.

The foregoing operational cycle may be repeated to continue to simultaneously pre-form and crimp surgical clips **1114** until the supply of surgical clips **1114** is exhausted.

FIGS. **15**A and **15**B are partial cross-sectional top views of a distal portion of another example end effector **1502**, according to one or more embodiments of the present disclosure. The end effector **1502** may be similar in some respects to the end effectors **1102** and **1302** of FIGS. **11**A-**11**C and **13**A-**13**D, respectively, and therefore may be best understood with reference thereto, where like numerals will correspond to like components not described again in detail. FIGS. **15**A and **15**B illustrate progressive views of the end effector **1502** during example operation of feeding surgical clips **1114** into the jaw members **1104**, **1106** for crimping.

Referring first to FIG. **15**A, the end effector **1502** includes the elongate body **1108** and the jaw members **1104**, **1106** extend out of or otherwise protrude from the distal end **1110***b* of the body **1108**. The end effector **1502** further includes a clip track **1504** configured to contain and otherwise house the surgical clips **1114**. In some embodiments, the body **1108** defines or otherwise provides the clip track **1504**. In other embodiments, however, the clip track **1504** may comprise a separate structural component that is removably positioned within the body **1108**. Similar to the prior embodiments, the surgical clips **1114** may exhibit the diverging opening angle **1120**, which allows the surgical clips **1114** to be arranged within the clip track **1504** in a generally nested relationship. While five surgical clips **1114** are depicted in FIG. **15**A, more or less than five may be employed, without departing from the scope of the disclosure.

The end effector **1502** may further include a pre-forming region **1506** configured to receive and progressively transition the surgical clips **1114** from the wide state to the tissue-ready state. In some embodiments, the pre-forming region **1506** is defined by the body **1108**, but may alternatively be provided by the clip track **1504**. In yet other embodiments, the pre-forming region **1506** may comprise a separate structural component that is removably positioned within the body **1108**. As illustrated, the pre-forming region **1506** may comprise opposed ramped (angled) surfaces **1508** configured to successively reduce (minimize) the diverging opening angle **1120** of the surgical clips **1114** as they are advanced distally toward the jaw members **1104**, **1106**. The surgical clips **1114** may be plastically or elastically deformed as they traverse the pre-forming region **1506** in the distal direction.

The end effector **1502** further includes a feeder shoe **1510** configured to apply an axial load in the distal direction on the surgical clips **1114** positioned within the clip track **1504**. The axial load forces the surgical clips **1114** through the pre-forming region **1506** to transition the surgical clips **1114** from wide to tissue-ready states. In some embodiments, as illustrated, the feeder shoe **1510** may include a compression spring **1512** that engages a proximal end of the feeder shoe **1510** to provide a passive and constant axial load on the surgical clips **1114**. The spring force of the compression spring **1512** may be sufficient to force the surgical clips **1114** through the pre-forming region **1506** until the last surgical clip **1114** is progressively and properly transitioned to the tissue-ready state. In other embodiments, however, the feeder shoe **1510** may include or comprise an actuatable device or mechanism that selectively supplies the axial load. In such embodiments, the feeder shoe **1510** may apply the axial load only to advance the surgical clips **1114** a predetermined distance within the clip track **1504**, and thereby progressively advance the surgical clips **1114** through the pre-forming region **1506**.

A feedbar **1514** may be included and configured to engage and move the distal-most surgical clip **1114***a* from the pre-forming region **1506** and to the jaw members **1104**, **1106**. In some embodiments, the feedbar **1514** may extend to the end effector **1502** from a drive housing (e.g., the drive housings **206**, **606** of FIGS. **2** and **6**, respectively). At the drive housing, the feedbar **1514** may be operatively coupled to an actuating mechanism or device configured to cause longitudinal translation of the feedbar **1514**. In one embodiment, for example, the feedbar **1514** may be operatively coupled to and otherwise extend from one or more translatable driven gears, such as the first and second driven gears **504***a,b* of FIG. **5**. In embodiments with an articulable wrist, the feedbar **1514** may be made of a flexible material and extend through the wrist. Alternatively, the feedbar **1514** may be operatively coupled to a cable-driven worm gear arranged distal to the wrist and the associated drive cable(s) that moves the worm gear extend through the wrist.

With additional reference to FIG. **15**B, example operation of feeding the surgical clips **1114** into the jaw members **1104**, **1106** is now provided. In FIG. **15**A, the feeder shoe **1510** is shown urging the stack of surgical clips **1114** in the distal direction and through the pre-forming region **1506**. As they traverse the ramped surfaces **1508** of the pre-forming region **1506**, the surgical clips **1114** progressively transition from the wide state to the tissue-ready state. More specifically, the legs **1118** of each surgical clip **1114** slidably engage the inner walls of the pre-forming region **1506** as the surgical clips **1114** advance distally. The distally converging and ramped configuration of the ramped surfaces **1508** progressively reduces the diverging opening angle **1120** to produce tissue-ready surgical clips at or near the distal end of the ramped surfaces **1508**.

As illustrated in FIG. **15**A the distal-most surgical clip **1114***a* has been transitioned to the tissue-ready state. To advance the distal-most surgical clip **1114***a* toward the jaw members **1104**, **1106**, the feedbar **1514** may be advanced distally until engaging the distal-most surgical clip **1114***a*.

In FIG. **15**B, the distal-most surgical clip **1114***a* is shown as having traversed the pre-forming region **1506** and being advanced by the feedbar **1514** to be received within the jaw members **1104**, **1106**. In embodiments including the grooves **1124** defined on each jaw member **1104**, **1106**, the legs **1118** may spring outward and seat themselves within the grooves **1124**, which may help retain the surgical clip **1114** in place. Otherwise, the distal-most surgical clip **1114** may be retained between the jaw members **1104**, **1106** via an interference. At this point, the jaw members **1104**, **1106** may be actuated to collapse or close and thereby crimp the distal-most surgical clip **1114***a* therebetween.

Once the distal-most surgical clip **1114***a* is advanced out of the pre-forming region **1506**, the feeder shoe **1510** may be configured to distally advance the remaining surgical clips **1114** positioned within the clip track **1504** and further into the pre-forming region **1506**. As a result, the penultimate surgical clip **1114***b* may be fully transitioned from the wide state to the tissue-ready state and ready to be advanced distally to the jaw members **1104**, **1106** with the feedbar **1514**.

The foregoing operational cycle may be repeated to continue to progressively form tissue-ready surgical clips **1114** and advance the tissue-ready surgical clips **1114** to the jaw members **1104**, **1106** to be crimped until the supply of surgical clips **1114** is exhausted.

Embodiments disclosed herein include:

A. An end effector for a surgical clip applier that includes an elongate body, a clip track provided within the body and containing one or more surgical clips, wherein each surgical clip includes a crown and a pair of legs extending longitudinally from the crown and diverging from each other at a diverging opening angle, a pre-forming region provided within the body and arranged to receive and deform the one or more surgical clips from a first state, where the pair of legs diverge at the diverging opening angle, and a second state, where the diverging opening angle is minimized, and first and second jaw members positioned at a distal end of the body and arranged to receive the one or more surgical clips from the pre-forming region in the second state.

B. A method of operating an end effector of a surgical clip applier that includes positioning the end effector adjacent a patient for operation, the end effector including an elongate body, a clip track provided within the body and containing one or more surgical clips, wherein each surgical clip includes a crown and a pair of legs extending longitudinally from the crown and diverging from each other at a diverging opening angle, a pre-forming region provided within the body and arranged to receive the one or more surgical clips from the clip track, and first and second jaw members positioned at a distal end of the body and arranged to receive the one or more surgical clips from the pre-forming region. The method further including advancing a distal-most surgical clip of the one or more surgical clips from the clip track to the pre-forming region, deforming the distal-most surgical clip in the pre-forming region from a first state, where the pair of legs of the distal-most surgical clip diverge at the diverging opening angle, and a second state, where the diverging opening angle is minimized, and advancing the distal-most surgical clip from the pre-forming region to the first and second jaw members in the second state.

C. A surgical clip applier that includes a drive housing, an elongate shaft that extends from the drive housing, and an end effector arranged at a distal end of the elongate shaft. The end effector includes an elongate body, a clip track provided within the body and containing one or more surgical clips, wherein each surgical clip includes a crown and a pair of legs extending longitudinally from the crown and diverging from each other at a diverging opening angle, a pre-forming region provided within the body and arranged to receive and deform the one or more surgical clips from a first state, where the pair of legs diverge at the diverging opening angle, and a second state, where the diverging opening angle is minimized, and first and second jaw members positioned at a distal end of the body and arranged to receive the one or more surgical clips from the pre-forming region in the second state.

Each of embodiments A, B, and C may have one or more of the following additional elements in any combination: Element 1: wherein the one or more surgical clips comprises a plurality of surgical clips arranged in series within the clip track, and wherein more distal surgical clips of the plurality of surgical clips are at least partially nested within more proximal surgical clips of the plurality of surgical clips. Element 2: wherein the pre-forming region comprises opposed structural surfaces that converge toward one another in a distal direction. Element 3: wherein the pre-forming region is defined by the first and second jaw members. Element 4: wherein the first and second jaw members are actuated a first time to deform a given surgical clip of the one or more surgical clips from the first state to the second state, and actuated a second time to crimp the given surgical clip between the first and second jaw members. Element 5: further comprising a feeder shoe that applies an axial load on the one or more surgical clips positioned within the clip track to promote sequential feeding of the one or more surgical clips, and a feedbar engageable with a distal-most surgical clip of the one or more surgical clips to convey the distal-most surgical clip to the pre-forming region and subsequently to the first and second jaw members. Element 6: further comprising a retention member that engages one or more surgical clips located distally within the clip track and prevents the one or more surgical clips from advancing into the pre-forming region. Element 7: wherein the retention member comprises a passive biasing device. Element 8: wherein the feeder shoe further comprises a compression spring that supplies the axial load. Element 9: wherein the feedbar advances the distal-most surgical clip through the pre-forming region such that the pair of legs of the distal-most surgical clip slidably engage the inner walls of the pre-forming region to transition the distal-most surgical clip to the second state. Element 10: wherein the feedbar comprises a first engagement member engageable with the distal-most surgical clip, and a second engagement member located proximal to the first engagement member and simultaneously engageable with a penultimate surgical clip of the one or more surgical clips. Element 11: wherein a distal end of the clip track provides a ramped portion that repositions the one or more surgical clips positioned at the ramped portion such that the feedbar is able to engage and distally advance the one or more surgical clips. Element 12: wherein a distal end of the pre-forming region is aligned with the first and second jaw members.

Element 13: wherein the pre-forming region comprises opposed structural surfaces that converge toward one another in a distal direction, and wherein advancing the distal-most surgical clip to the pre-forming region comprises engaging the distal-most surgical clip with a feedbar, conveying the distal-most surgical clip to the pre-forming region with the feedbar, and advancing the distal-most surgical clip through the pre-forming region such that the pair of legs of the distal-most surgical clip slidably engage the opposed structural surfaces of the pre-forming region and transition the distal-most surgical clip to the second state. Element 14: wherein the pre-forming region is defined by the first and second jaw members, and wherein deforming the distal-most surgical clip in the pre-forming region comprises conveying the distal-most surgical clip to the pre-forming region with a feedbar, and actuating the first and second jaw members a first time to deform the distal-most surgical clip to the second state within the pre-forming region. Element 15: wherein the feedbar comprises a first engagement member engageable with the distal-most surgical clip, and a second engagement member located proximal to the first engagement member, and wherein advancing the distal-most surgical clip to the first and second jaw members in the second state further comprises advancing the distal-most surgical clip to the first and second jaw members with the feedbar and simultaneously engaging the second engagement member on a penultimate surgical clip of the one or more surgical clips and advancing the penultimate surgical clip to the pre-forming region, and actuating the first and second jaw members a second time to crimp the distal-most surgical clip and simultaneously deform the penultimate surgical clip to the second state within the pre-forming region.

Element 16: further comprising an articulable wrist joint interposing the end effector and the elongate shaft.

By way of non-limiting example, exemplary combinations applicable to A, B, and C include: Element 3 with Element 4; Element 5 with Element 6; Element 6 with Element 7; Element 5 with Element 8; Element 5 with Element 9; Element 5 with Element 10; Element 5 with Element 11; and Element 14 with Element 15.

Therefore, the disclosed systems and methods are well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the teachings of the present disclosure may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope of the present disclosure. The systems and methods illustratively disclosed herein may suitably be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the elements that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

As used herein, the phrase "at least one of" preceding a series of items, with the terms "and" or "or" to separate any of the items, modifies the list as a whole, rather than each member of the list (i.e., each item). The phrase "at least one of" allows a meaning that includes at least one of any one of the items, and/or at least one of any combination of the items, and/or at least one of each of the items. By way of example, the phrases "at least one of A, B, and C" or "at least one of A, B, or C" each refer to only A, only B, or only C; any combination of A, B, and C; and/or at least one of each of A, B, and C.

What is claimed is:

1. An end effector for a surgical clip applier, comprising:

an elongate body; first and second jaw members positioned at a distal end of the body;

a clip track provided within the body;

one or more surgical clips contained within the clip track, wherein each surgical clip includes a crown and a pair of legs extending longitudinally from the crown and diverging from each other at a diverging opening angle;

a pre-forming region defined by the clip track and comprising opposed structural surfaces that converge toward one another in a distal direction; and

a feedbar engageable with a distal-most surgical clip of the one or more surgical clips to advance the distal-most surgical clip through the pre-forming region and thereby transition the distal-most surgical clip from a first state, where the pair of legs diverge at the diverging opening angle, to a second state, where the diverging opening angle is minimized;

and the distal-most surgical clip is prepared to be received by the first and second jaw members and crimped.

2. The end effector of claim **1**, wherein the one or more surgical clips comprises a plurality of surgical clips arranged in series within the clip track, and wherein more distal surgical clips of the plurality of surgical clips are at least partially nested within more proximal surgical clips of the plurality of surgical clips.

3. The end effector of claim **1**, further comprising

a feeder shoe that applies an axial load on the one or more surgical clips positioned within the clip track to promote sequential feeding of the one or more surgical clips;

wherein the feedbar conveys the distal-most surgical clip to the first and second jaw members.

4. The end effector of claim **3**, further comprising a retention member that engages the one or more surgical clips located distally within the clip track and prevents the one or more surgical clips from advancing into the pre-forming region.

5. The end effector of claim **4**, wherein the retention member comprises a passive biasing device.

6. The end effector of claim **3**, wherein the feeder shoe further comprises a compression spring that supplies the axial load.

7. The end effector of claim **3**, wherein the feedbar advances the distal-most surgical clip through the pre-forming region such that the pair of legs of the distal-most surgical clip slidably engage the inner walls of the pre-forming region to transition the distal-most surgical clip to the second state.

8. The end effector of claim **3**, wherein a distal end of the clip track provides a ramped portion that repositions the one or more surgical clips positioned at the ramped portion such that the feedbar is able to engage and distally advance the one or more surgical clips.

9. The end effector of claim **1**, wherein a distal end of the pre-forming region is aligned with the first and second jaw members.

10. The end effector of claim **1**, wherein the one or more surgical clips comprise a proximal surgical clip and a distal surgical clip, and wherein, when the proximal and distal surgical clips are contained within the clip track, the pair of legs of the proximal surgical clip extends past and partially overlaps the pair of legs of the distal surgical clip.

11. A method of operating an end effector of a surgical clip applier, comprising:

positioning the end effector adjacent a patient for operation, the end effector including:

an elongate body; first and second jaw members positioned at a distal end of the body;

a clip track provided within the body;

one or more surgical clips contained within the clip track, wherein each surgical clip includes a crown and a pair of legs extending longitudinally from the crown and diverging from each other at a diverging opening angle;

a pre-forming region defined by the clip track and comprising opposed structural surfaces that converge toward one another in a distal direction;

distally advancing a distal-most surgical clip of the one or more surgical clips through the pre-forming region with a feedbar;

deforming the distal-most surgical clip in the pre-forming region from a first state, where the pair of legs of the distal-most surgical clip diverge at the diverging opening angle, to a second state, where the diverging opening angle is minimized and the distal-most surgical clip is prepared to be received by the first and second jaw members and crimped; and

advancing the distal-most surgical clip from the pre-forming region to the first and second jaw members in the second state with the feed bar.

12. The method of claim **11**, wherein distally advancing the distal-most surgical clip through the pre-forming region comprises

advancing the distal-most surgical clip through the pre-forming region such that the pair of legs of the distal-most surgical clip slidably engage the opposed structural surfaces of the pre-forming region and transition the distal-most surgical clip to the second state.

13. A surgical clip applier, comprising:

a drive housing;

an elongate shaft that extends from the drive housing; and

an end effector arranged at a distal end of the elongate shaft, the end effector including:

an elongate body; first and second jaw members positioned at a distal end of the body;

a clip track provided within the body;

one or more surgical clips contained within the clip track, wherein each surgical clip includes a crown and a pair of legs extending longitudinally from the crown and diverging from each other at a diverging opening angle;

a pre-forming region defined by the clip track and comprising opposed structural surfaces that converge toward one another in a distal direction; and

a feedbar engageable with a distal-most surgical clip of the one or more surgical clips to advance the distal-most surgical clip through the pre-forming region and thereby transition the distal-most surgical clip from a first state, where the pair of legs diverge at the diverging opening angle, to a second state, where the diverging opening angle is minimized and the distal-most surgical clip is prepared to be received by the first and second jaw members and crimped.

14. The surgical clip applier of claim **13**, further comprising an articulable wrist joint interposing the end effector and the elongate shaft.

15. The surgical clip applier of claim **13**, wherein the one or more surgical clips comprise a proximal surgical clip and a distal surgical clip, and wherein, when the proximal and distal surgical clips are contained within the clip track, the pair of legs of the proximal surgical clip extends past and partially overlaps the pair of legs of the distal surgical clip.

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